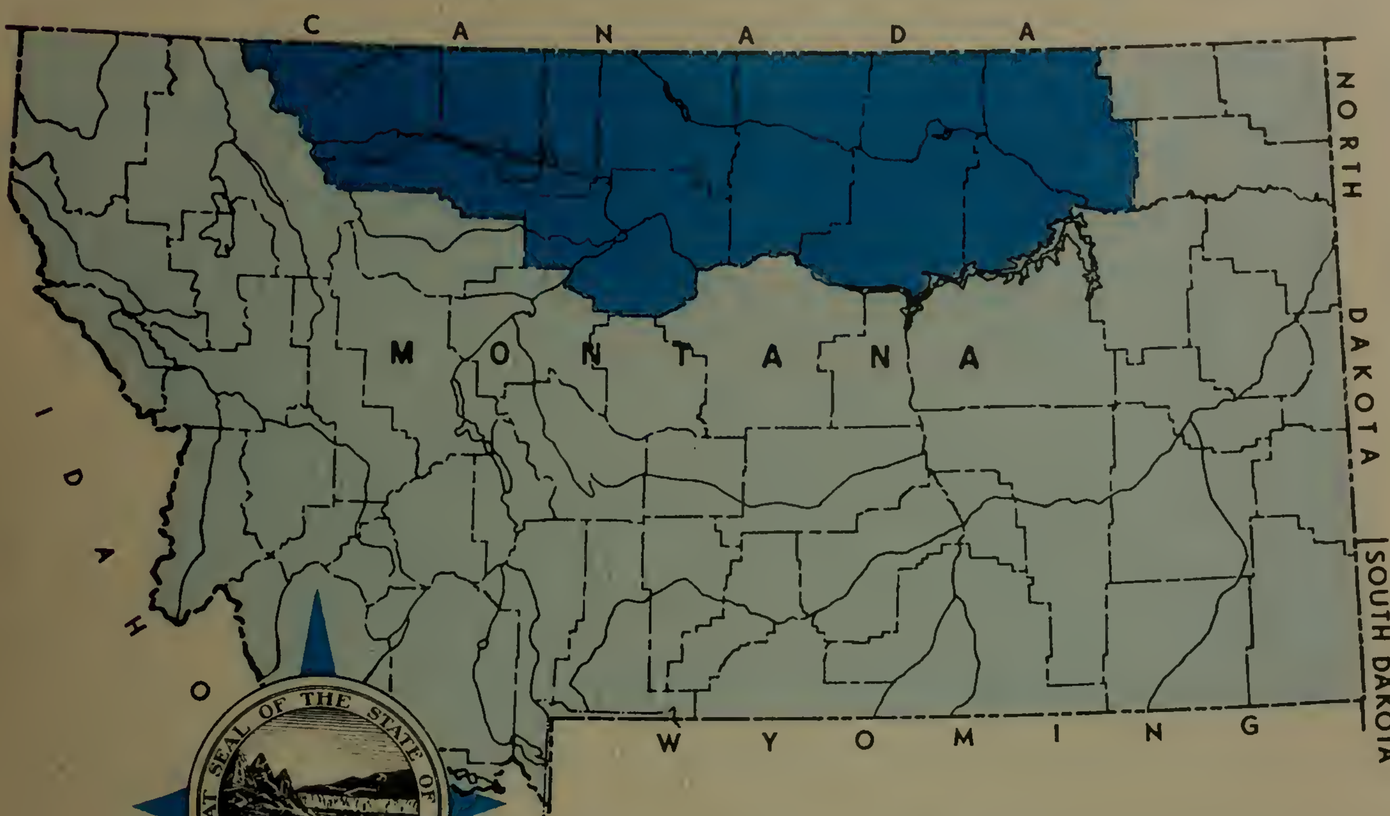
Water Conservation - Report

PRELIMINARY SURVEY REPORT

NORTH CENTRAL WATER CONSERVANCY DISTRICT



Montana State
Water Resources Board

HDR

HENNINGSON, DURHAM & RICHARDSON
HELENA, MONTANA
PARSONS, BRINCKERHOFF, QUADE & DOUGLAS INC.
NEW YORK

HENNINGSON, DURHAM & RICHARDSON, INC.
PARSONS, BRINCKERHOFF, QUADE & DOUGLAS, INC.

A Joint Venture

200 KIEWIT PLAZA
OMAHA, NEBRASKA 68131

December 28, 1970

Montana Water Resources Board
Sam W. Mitchell Building
Helena, Montana 59601

Re: Report on Preliminary Survey of the North Central Water Conservancy District

Gentlemen:

In accordance with our engineering agreement dated 10 April 1970, we herewith submit our report on the preliminary survey of the North Central Montana Water Conservancy District.

The conclusions and recommendations are summarized together with the Topical Summary preceding the main body of the report.

The information and studies which led to our conclusions are presented in detail in the main body of the report.

We have enjoyed working with the Water Resources Board and members of your staff on this study and look forward to being of service to you again in the near future.

Respectfully submitted,

HENNINGSON, DURHAM & RICHARDSON, INC.
PARSONS, BRINCKERHOFF, QUADE & DOUGLAS, INC.

R. A. Rohling, P.E.
for the Joint Venture
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NORTH CENTRAL

MONTANA

WATER CONSERVANCY DISTRICT

PRELIMINARY SURVEY REPORT

PREPARED FOR

MONTANA WATER RESOURCES BOARD

PREPARED BY

HENNINGSON, DURHAM & RICHARDSON, INC.
PARSONS, BRINKERHOFF, QUADE & DOUGLAS, INC.
A JOINT VENTURE

1970

SURVEY AND PRELIMINARY REPORT

NORTH CENTRAL MONTANA WATER CONSERVANCY DISTRICT

SUMMARY, CONCLUSIONS & RECOMMENDATIONS

SURVEYAND PRELIMINARY REPORT

NORTH CENTRAL MONTANA WATER CONSERVANCY DISTRICT

TOPICAL SUMMARY

PART I - PURPOSE OF STUDY AND REPORT. The purpose of this study was to conduct a preliminary survey of water resources for a proposed conservancy district within the North Central-Nine County area of Montana. The ultimate objective of the survey was to produce a report summarizing the information (analyzed and elaborated during its performance) to enable a decision to be made concerning the preliminary feasiblity of establishing a conservancy district. In addition, the survey will provide a basic determination of the water availability and water supply needs to realize development of the total water and land resources in the North Central Montana area.

PART II - CHARACTERISTICS OF STUDY AREA

A. The Study Area includes Glacier, Pondera, Chouteau, Liberty, Toole, Hill, Blaine, Phillips and Valley Counties, an area of approximately 29,000 sq. miles.

B. Climate - a semi-arid region with total average precipitation of 13 inches per year. Growing season varies from 90 to 120 days.

C. 1970 population of 9 counties is 73,007, a gross loss of approximately 15% from the 1960 census. Thirty percent of population lives or is employed directly on farms and ranches. Any direct improvement to agriculture would have substantial positive economic impact on the entire area.

PART III - PROJECT LANDS

Total Acres in Study Area	18,677,000
Total Acres in range land	12,035,000
Total Acres in forest and other	1,167,000
Total Acres in cropland	5,475,000
Total Acres presently under irrigation	415,000
Total Acres available for potential irrigation	2,774,000
Total Acre-Feet of water available for irrigation development	827,000

Potentially irrigable lands, as defined in this study, are lands suitable for irrigation by gravity or sprinkler methods. The land must have soil, topography and drainage features which will withstand a sustained irrigated agriculture.

The intensity of the land classification survey for potential

irrigation development should be considered as a general reconnaissance survey, and any future irrigation project development should be based on a detailed study. The areas outlined as potentially irrigable in this report show land which has been classified as class 1, 2 or 3 by the general reconnaissance survey.

PART IV - CONSERVANCY DISTRICT ECONOMY

A. Most significant impact upon the total area economy as a result of a district - livestock production as measured by cash receipts and spendable income.

B.	Wheat declining	1956 - 67% of cash receipts
		1967 - 55% of cash receipts
	Livestock increasing	1956 - 20% of cash receipts
		1967 - 34% of cash receipts

C. Better agricultural management possible from more and better diversification of land use.

D. The diversified farm most important to economy of area in terms of cash receipts.

E.	Total present cropland	Dry	5,000,000+
		Irrigated	415,000
	Total potential cropland	Dry	5,000,000
		Irrigated	875,000
	Total present number cattle and calves		508,000
	Total potential number cattle and calves, based upon increased irrigation		790,000

PART V - WATER SUPPLY AND REQUIREMENTS

A. There are 65 towns and municipalities in the Study Area. Twenty-nine of these communities need a new source of supply, many of which also need new water distribution systems. Twelve other communities need to expand upon their existing water source. Twenty-five of the communities which have private septic tanks are programmed for sanitary sewer collection systems and waste treatment facilities.

B. It is estimated that by the year 2020, municipal and rural domestic requirements, including minor industrial requirements, will be 7,740 A. F. annually. It is estimated that stock water requirements will increase to between 15,000 A. F. to 20,000 A. F. annually over this same period. If all of the potentially irrigable

lands as shown in this report were irrigated, the annual irrigation water requirement would be approximately 5 million A. F.

Although water availability for human and animal consumption is of paramount importance, it can readily be seen that the amount of water required for this use is almost insignificant compared to the irrigation requirement. It can also be seen that there is not enough water available to meet all of the water requirements.

C. Water quality in the Study Area is dependent primarily on total dissolved solids. In many areas ground water with 1000 ppm or more total dissolved solids makes it unsuitable for all but industrial use. The quality of surface water is generally good for irrigation even during periods of low flow. With increased irrigation the total dissolved solids load will increase. The amount of this increase will have to be determined in detailed feasiblity studies.

PART VI - WATER AVAILABILITY. Based on an evaluation of historical USGS stream gaging station records, there is additional water available in the Study Area in the following amounts:

	Average Annual Flow	65% Average Flow	Deductions & Depletions	Available for Development
Milk River	523,400 AF	340,000	104,000	236,000
Marias River	676,000	440,000	122,000	318,000
Missouri River (contributed from Study Area)	138,000	90,000	--	90,000
St. Mary River (U. S. share)	271,000	176,000	149,000	27,000
Waterton-Belly Rivers (U. S. share)	240,000	156,000	--	156,000
				827,000

PART VII - EXISTING AREA WATER DEVELOPMENT. A list of all storage projects within the area of study, of 50 A. F. or larger, is included in Appendix H. The principal existing impoundment and supply works are as follows:

A. Fort Peck Dam and Reservoir
B. Tiber Dam and Reservoir
C. Fresno Dam and Reservoir
D. Nelson Dam and Reservoir
E. Milk River Irrigation Unit

The principal use of ground water in the area is for domestic and livestock requirements, with only a limited amount being used for industrial requirements. There is approximately one ground water well or spring for every four square miles in the Study Area. Use is limited primarily by poor water quality.

PART VIII - BENEFIT-COST ANALYSIS

BENEFITS

a. Water requirements for irrigation many times more than all other uses. For this reason, irrigation benefits received most attention during this survey.

b. Benefits from irrigation are tangible and intangible. In our economic evaluation, only those benefits of a tangible nature which are measurable in monetary terms are considered herein. Examples:

Increase in net farm and ranch income which accrue directly to the water user.

Increase in profits to processors and handlers of increased agricultural products.

Public benefit by enhancement of economic growth.

c. Typical increased irrigated land usage:

50% irrigated alfalfa
30% irrigated pasture
20% irrigated small feed grains, barley and corn silage.

d. Based upon above assumed land use, the direct benefits to water user associated with increased crop production were computed as:

$ 23.97/acre for cash crop production or self-use in livestock production.

$14.25/acre for increased livestock production.

Approx. Total: $40.00/acre direct benefits.

$20.00/acre indirect benefits to other than immediate water user.

$60.00/acre Total Benefit from irrigation.

e. Municipal and industrial benefits:

Conrad, Cut Bank, Browning, Santa Rita, Shelby, Havre, Chinook, Brady and Fort Benton, + 29 other smaller towns.

f. Recreation, fish and wildlife benefits:

Lonesome Lake - Bowdoin Wildlife Refuge - Chain of Lakes - U. L. Bend Project.

g. Flood Control Benefits:

Shelby, Nashua, Browning, Glasgow, Beaver Creek.

h. Other benefits:

General area upgrading economically.
General area redevelopment.

COSTS

a. Construction Costs:

Escalated cost figures from existing reports to 1970 level where possible.

General cost curves developed from available cost information for similar projects in northern plains area.

b. Operation, maintenance and replacement costs (OM&R):

Same techniques used as in developing construction costs.

c. Total annual equivalent costs:

Construction cost amortized over 100 years at 5 1/8% interest plus annual OM&R costs.

PART IX - OPTIMIZATION MODEL. A linear programming optimization model was developed as a method of analyzing the components of the conservancy district water system. The model solved for values of system variables giving maximum benefits, minimum costs, and maximum net benefits on an annual basis. Variables considered related to the operation of existing system components and the operation and sizing of proposed system components. In all, there were 1,178 of these unknowns restricted by 956 equations pertaining to water system continuity, proposed component capacity and Indian water rights.

The optimization model was used for project selection. Results of this selection, which involved 69 proposed projects, for each of the

objective functions are as follows:

a. Number of projects selected for maximum benefit: 47.

b. Number of projects selected for minimum cost: 19.

c. Number of projects selected for maximum net benefits: 44.

PART X - FUNCTIONAL PLAN OF DEVELOPMENT

A. The project plan provides for using the available water in an efficient and beneficial manner and is based upon the projects that are shown in reports by various agencies and individuals. Inasmuch as irrigation water requirements far exceed the total other water requirements for this area, the functional plan has been developed by using irrigation demands. A significant point brought out in the study was that the Milk River flows are not being fully used.

If 65% of the average annual stream flows are assumed to be firmly available for irrigation and other development, a total of 827,000 A. F. of water is available to the Study Area which is not presently being used.

The plan as formulated includes the following major elements:

a. Additional Storage Sites on Milk River and Tributaries.

b. St. Mary River Diversion to Upper Marias Area.

c. Marias - Milk Unit.

d. Fort Peck - Willow Creek Diversion.

e. Irrigation Development on Reservation Lands.

f. Municipal and Rural Water Supply.

g. Flood and Erosion Control.

h. Drainage and Mosquito Control.

i. Water Master Program.

j. Fish, Wildlife and Recreation.

PART XI - FINANCIAL ANALYSIS

A. Total taxable value of real property in Nine-County Study Area is $34,652,884.

Under law, the maximum mill levy for conservancy district operation and administration of 2 mills and debt service of 3 mills will raise:

	2 mills	$ 69,306
	3 mills	103,959
Total	5 mills	$173,265

B. There are currently Federal, State and locally financed programs (not necessarily available funds) under which all of the projects covered in this study can be financed and the total water resources of the area developed. However, due to the ever-increasing national demand for the tax dollar, timely implementation of water resource development may not be possible through these programs and local debt financing should be considered.

C. Opinion of bond counsel indicates that substantial legislative revision may be required in order to properly implement local debt financing.

PART XII - PROPOSED CONSERVANCY DISTRICT BOUNDARY. Considering the type of projects anticipated under a conservancy district and the benefits which would accrue from these projects, drainage basins would form an appropriate criterion for establishing the boundaries of the district. It is recommended that all of the Milk and Marias River watersheds (within the United States) be included in further studies of the proposed district.

SURVEY AND PRELIMINARY REPORT

NORTH CENTRAL MONTANA WATER CONSERVANCY DISTRICT

CONCLUSIONS

1. The survey and analysis conducted in the preliminary feasibility study of water development in the Study Area leads one to the definite conclusion that the total economic development and water development of the State of Montana and the Study Area could and would be enhanced by the formation and operation of a water conservancy district recognizing that specific details of such operations could only be determined by more detailed investigations.

2. There is additional water available in the Study Area.

3. Milk River and Marias River flows are not presently being fully utilized.

4. Available water can be put to beneficial use.

5. Full water development could be accomplished using projects which have been shown to be economically feasible.

6. There is not enough water to fully develop the irrigation requirement of the Study Area.

7. Significance of wheat production is declining; livestock production is becoming increasingly important.

8. The diversified farm is the most important to the area in terms of total cash receipts.

9. Most significant impact upon the total area economy as a result of a conservancy district would be increased livestock production.

10. Water requirements for irrigation are many times more than for all other uses.

11. A significant part of the benefits associated with irrigation are intangible in nature and cannot easily be expressed in monetary terms.

12. The costs of the proposed projects are such that a large amount of Federal financing will be required.

13. There are many existing Federal, State and local programs available for water resources development.

Advantages of a Conservancy District:

1. Better utilization of existing water resources would be provided.

2. A coordinated effort would be provided for getting the most beneficial use from the remaining water resources.

3. Entity such as a conservancy district has advantage in Federal grant market because of overall master planning concept as opposed to several individual projects.

4. Under a conservancy district, multiple purposes such as flood and erosion control, fish, wildlife and recreation development would be included in planning of all projects.

5. A cooperative regional effort could more efficiently accomplish water resources development than several individual groups working toward their own specific goals.

6. A conservancy district could provide better water management for an entire river basin.

7. Conservancy district would act as a catalyst in total area development.

Disadvantages:

1. It is possible for most of the projects in the plan to be developed without a conservancy district, although it is doubtful that very many would without coordinated area-wide planning such as would be provided under a conservancy district.

2. For optimum water management, individual water rights should be pooled for the mutual benefit of all. Historically, assignment of water rights, such as is done in the formation of irrigation districts, has been a delicate matter in Montana and may be a personal type hindrance to the formation of a Conservancy District in the case of some individuals.

SURVEY AND PRELIMINARY REPORT

NORTH CENTRAL MONTANA WATER CONSERVANCY DISTRICT

RECOMMENDATIONS

1. Storage and regulation sites along the lower portion of the Milk River should be sought and investigated in any further studies to determine feasibility of the conservancy district.

2. Discussions with the Canadian Section of the International Joint Commission should be initiated to more accurately determine the amount of water which can practically be considered for water development within the U. S.

3. Consideration should be given to including all of the Milk and Marias Rivers drainage areas (within the United States) in any further detailed feasibility studies.

4. Legal aspects of Conservancy District Statutes, particularly those concerning local and Federal financing provisions, should be given careful scrutiny before a district is formed.

PART I - INTRODUCTION

PART I

INTRODUCTION

A. GENERAL

The price of wheat today is essentially the same as it was 30 years ago. During this time, however, farm production costs have continued to increase. The prices the farmer has to pay for farm machinery and equipment and for the essentials such as food and clothing have gone up several fold in the last 30 years. These farm conditions have led to increased farm sizes and, wherever possible, diversification away from complete dependence on a dryland wheat economy.

In an area highly oriented toward agriculture, as the Study Area is, the economic conditions in the towns and urban areas are a direct reflection of the economic conditions on the farms. When crops are good, the farmers have money to replace worn equipment; when bad, the old combine has to make do for another year.

Viewed against these farming conditions, it is easy to see why the Study Area has lost 15 percent of its population in the last 10 years. Up and down the Hi-Line, one small community after another is on the verge of extinction.

Historically, throughout the semi-arid western states, water development has meant economic development. Recognizing this and that coordinated area wide planning would be required to put the water resources of Montana to optimum multi-purpose use, the State of Montana has undertaken a vigorous, far-sighted program to inventory and evaluate the water resources and water needs of the State.

The multiple uses, in general, encompass municipal supply, irrigation, power, flood control, recreation, navigation, low flow augmentation, and wild life. All of these uses are not always compatible with all desires. Sooner or later, the maximum supply of water that can be made regularly available in each drainage area must be put to its best coordinated use.

B. AUTHORITY

Recognizing that the water resources of the State of Montana should be put to optimum beneficial use, the Montana Legislature passed the Montana Water Resources Act of 1967 which created the Montana Water Resources Board. The objectives of the Water Act are as follows:

1. The general welfare of the people of Montana, in view of the State's population growth and expanding economy, requires that water resources of the state be put to optimum beneficial use and not wasted.

2. The public policy of the State is to promote the conservation, development and beneficial use of the State's water resources to secure maximum economic and social prosperity for its citizens.

3. The State, in the exercise of its sovereign power, acting through the water resources board, hereinafter created, shall coordinate development and use of the water resources of the State so as to effect full utilization, conservation and protection of its water resources.

4. The development and utilization of water resources, and the efficient, economic distribution thereof, are vital to the people in order to protect existing uses and to assure adequate future supplies for domestic, industrial, agricultural and other beneficial uses.

5. The water resources of the State must be protected and conserved to assure adequate supplies for public recreational purposes and for the conservation of wildlife and aquatic life.

6. The public interest requires the construction, operation and maintenance of a system of works for the conservation, development, storage, distribution and utilization of water, which said construction, operation and maintenance is a single object and is in all respects for the welfare and benefit of the people of the State.

7. It is necessary to coordinate local, state and federal water resource development and utilization plans and projects through a single agency of state government, hereinafter created and to be known as the "Montana Water Resources Board."

8. The greatest economic benefit to the people of Montana can be secured only by the sound coordination of development and utilization of water resources with the development and utilization of all other resources of the State.

9. To achieve these objectives, and to protect the waters of Montana from diversion to other areas of the nation, it is essential that a comprehensive, coordinated multiple-use water resource plan be progressively formulated, to be known as the "State Water Plan".

Subsequently in February of 1969, the Montana legislature enacted Senate Bill No. 67, Chapter No. 100 providing for the conservation and development of water and land resources of the State through the creation of conservancy districts. A copy of this legislation is included in the Appendix of this report. A water conservancy district is a political subdivision which covers a portion of one or more counties in Montana. It must contain at least $100,000 in taxable valuation. Such a district is intended to provide a variety of benefits for the area concerned. Early in 1970, the counties of Valley, Phillips, Blaine, Hill, Chouteau, Liberty, and Toole made a written request to the Water Board for a preliminary survey for the formation of a conservancy district within their boundaries. After preliminary hearings in these seven counties, the counties of Glacier and Pondera requested to be included in the preliminary survey, thereby increasing the Study Area to nine counties. In response to the nine county request, the Water Board had the option of conducting the survey itself or retaining the services of a cooperating agency.

The Water Board has directed that the preliminary survey be conducted by the joint-venture forces of Henningson, Durham & Richardson, Inc. of Helena and Omaha and Parsons, Brinckerhoff, Quade and Douglas, Inc. of New York.

C. PURPOSE OF SURVEY

The purpose of this study is to conduct a preliminary survey of water resources for a proposed conservancy district within the nine county area. The ultimate objective of the survey is to produce a report summarizing the information analyzed and elaborated during its performance to enable a decision to be made concerning the preliminary feasibility of establishing a conservancy district. Secondly, the preliminary survey shall form the foundation for a more detailed feasibility study in the event preliminary feasibility is indicated.

In addition, the preliminary survey will provide a basic determination of the water availability and water supply needs to realize development of the total water and land resources in the North Central Montana area. The data contained therein will assist in the preparation of a state-wide comprehensive water plan.

This study, in conformance with provisions of the Engineering Contract, is conceptual in approach and schematic in design. The study is supported by a collection of basic quantitative and qualitative data, the majority of which has been obtained through a secondary source. The concept encompasses present and projected aspects as a basis for funding, detailed design, construction, and operation of the proposed projects.

The tasks performed by the Consultant and the data presented herein have been accomplished with the goal of determining preliminary feasibility of a water conservancy district within the confines of the nine county study area. The Consultant has contacted various Federal, State and local agencies and collected data that pertains to the formation of a water conservancy district. This data has been evaluated and is partially presented herein.

Land use, both present and future, along with water availability and quality has been investigated as well as the present and projected demands. Existing and proposed water development projects were reviewed and included as input to a mathematical model of the Study Area. As a result of the review and evaluation of the basic data, sources of water availability have been identified and a functional plan of projects which will effectively utilize all of the water available to the Study Area is suggested.

The functional plan as suggested has been formulated to make full use of all of the available water. Legal and Financial opinions have been included and alternative choices of District Boundaries have been established.

D. COOPERATION AND ACKNOWLEDGMENTS

During the course of the survey excellent cooperation was received from agencies of the State of Montana, Federal Agencies, consulting engineers and others. The Montana State University Agricultural Extension Service, County Agents, County Commissioners, Tribal Councils, and local farmers and ranchers have provided valuable insight and assistance in the development of this preliminary survey. The Project Plan, as presented herein, represents the combined experience and judgment of many interested and qualified groups. Specific acknowledgment is made to the following groups and individuals who have given important aid in the development of the overall plan and in providing material for this and prior reports which affect the nine county Study Area:

State of Montana

Governor
Water Resources Board
Department of Health
Bureau of Mines and Geology
Fish and Game Commission
Planning and Economic Development Department
Extension Service, University of Montana
State Soil Conservation Committee

Federal Agencies

Omaha District, U. S. Corps of Engineers
Bureau of Reclamation
Soil Conservation Service
Geological Survey
Bureau of Land Management
Bureau of Indian Affairs
Weather Bureau
Bureau of Sport Fisheries and Wildlife
Agricultural Stabilization & Conservation Service
Bureau of Outdoor Recreation

Indian Tribal Councils

Blackfeet
Rocky Boy
Fort Belknap
Fort Peck

Consulting Engineers

Mueller Engineering
Theodore J. Wirth and Associates
Black & Veatch
Harold Hoskins & Associates
M. K. Botz

Due to the specialized nature of some aspects of this study, a number of highly qualified specialists were enlisted to assist in the preparation of this report. Dr. Lloyd Rixe and his associates at the economic consulting firm of TAP, Inc., Bozeman, wrote Part IV - "Economy of the Study Area" and provided most of the basic economic data used throughout the report.

Questions concerning legal aspects which arose during the course of this study were handled by Mr. Henry Loble and Mr. Peter Pauly of Loble, Picotte, and Loble in Helena. Questions concerning the practicality of

local bond financing were referred to Mr. Arthur Whitney of Dorsey, Marquart, Windhorst, West & Halladay in Minneapolis.

Special acknowledgment is rendered to the Director of the Montana Water Resources Board, Mr. Douglas G. Smith and to Mr. Orrin Ferris, Chief Engineer, and to the entire Water Board for their enthusiastic cooperation and assistance during this study.

PART II - CHARACTERISTICS OF STUDY AREA

PART II

CHARACTERISTICS OF STUDY AREA

A. PHYSICAL GEOGRAPHY

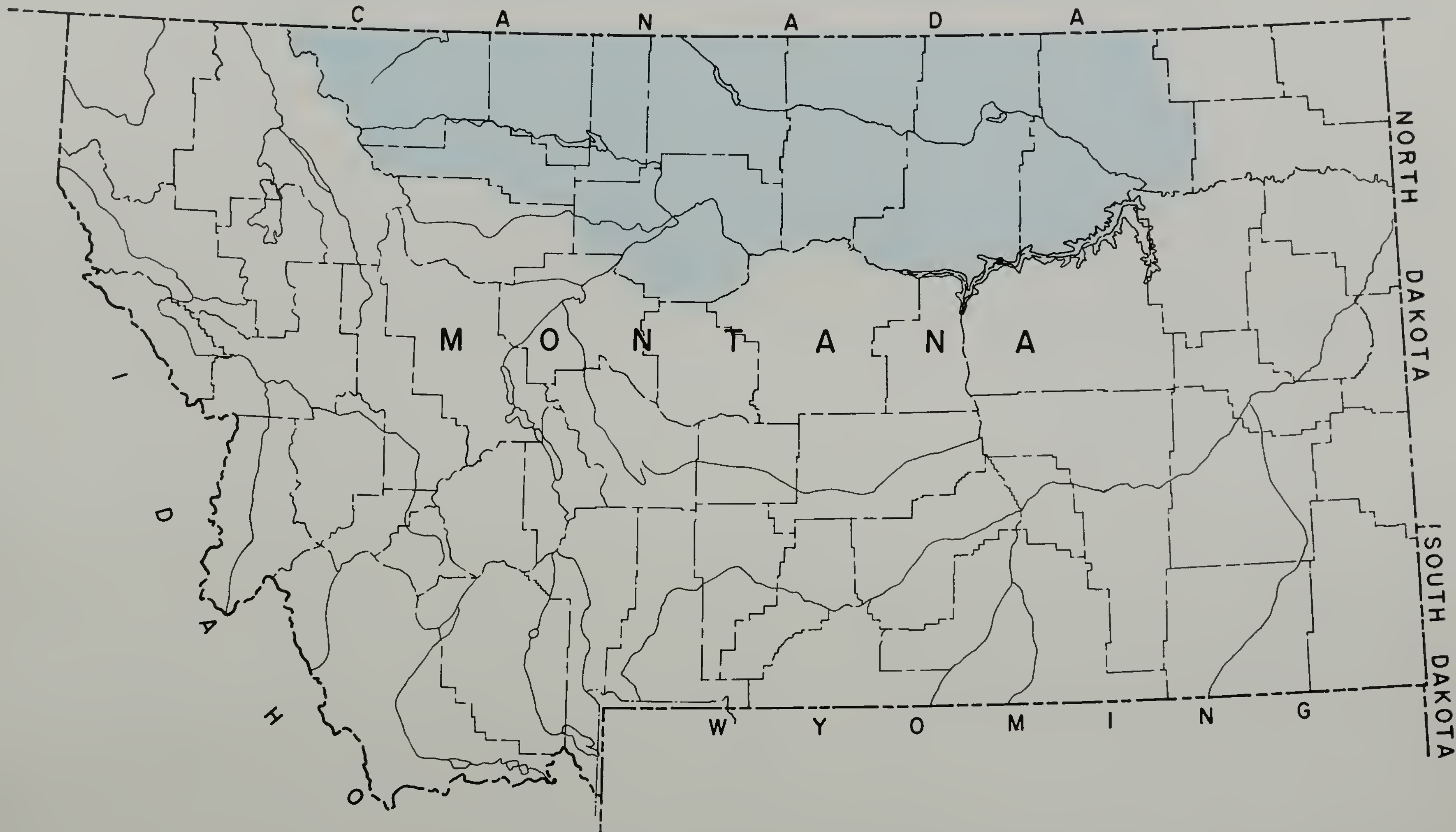
1. Location. The Study Area is situated in the North Central part of Montana and includes a portion of the northern tier of counties in Montana bounded on the north by the Provinces of Alberta and Saskatchewan, Canada, from the Continental Divide of Glacier and Pondera Counties easterly to and including Valley County. Nine counties covering an area of approximately 29, 000 sq. miles are included in this Study Area as shown in Figure II-1. These counties are: Glacier, Pondera, Chouteau, Liberty, Toole, Hill, Blaine, Phillips and Valley.

The study also encompasses all of the Blackfeet, Rocky Boy and Fort Belknap Indian Reservations as well as that portion of the Fort Peck Indian Reservation included in Valley County. (Roughly the western 1/3 of the Reservation).

2. Topography. Ground elevations vary from 10, 000 feet above mean sea level (MSL) in Glacier County to 2, 000 feet above MSL in the easterly portion of Valley County where the Missouri River leaves the county.

There are two major mountain ranges in the Study Area, the Rocky Mountains in Glacier and Pondera Counties including the Waterton-Glacier International Peace Park, and the Bear Paw Mountains in Blaine, Hill and Chouteau Counties. The Little Rocky Mountains are located contiguous to the Bear Paw Mountains in Hill and Chouteau County. The elevation of peaks in the Rocky Mountains is approximately 10, 000 feet above MSL and the Bear Paw and Little Rocky Mountain peaks have an elevation of near 6, 000 feet above sea level.

The Sweet Grass hills located in Toole County have a peak elevation of approximately 7, 000 feet above sea level and are the dominant geographical feature of northern Toole County. Large areas of bench lands are found in Valley, Phillips, Blaine and Glacier Counties, with the remainder of the area generally having rolling type terrain. Badlands are present adjacent to the Missouri River and Fort Peck Reservoir and bottom lands are found along the Milk, Marias, Teton and Missouri Rivers. Most of this river bottom area is irrigated at present as shown on the irrigation maps in Part X.



LOCATION OF STUDY AREA

FIGURE II-1

Two rivers, the Milk and Marias run from west to east through the Study Area and are tributary to the Missouri River which forms the southern boundary of the Study Area in Chouteau, Blaine, Phillips and Valley Counties. The Teton River also flows from west to east through part of Chouteau County before it joins the Marias River near the Marias-Missouri confluence. There are three major reservoirs in the Study Area, one on each of the three major rivers. The Tiber reservoir is located on the Marias River, the Fresno reservoir is located on the Milk River and the Fort Peck reservoir, the fourth largest reservoir in the world, is located on the Missouri River.

3. Climate. The Study Area varies from mountainous along the Continental Divide in the westerly portion of Glacier and Pondera Counties to rolling land in the remainder of the area, except for the Bear Paw and Little Rocky Mountains. The climate in the area varies according to the topography from a mountain oriented climate with winter chinook winds in the westerly portion of the area to a continental type of climate in the easterly portion of the area.

The winter chinook winds are prevalent in Glacier, Pondera, Chouteau, Liberty and Toole Counties. Following the cold invasions of air from Arctic sources, which occur several times each winter, the "chinook" usually starts to blow in about 36 to 48 hours, accompanied by a rapid warming often from well below 0°F. to above 32° in a very few hours. The chinook wind can be quite strong, at times reaching speeds in excess of 60 to 70 m. p. h. Gusts have been reported to have exceeded 100 m. p. h. locally a few times over the years. Strong wind of similar character sometimes precedes an Arctic cold air invasion.

Hill, Blaine, Phillips and Valley Counties have a continental type climate. This type of climate features cold winters, wet springs, warm summers and small amounts of precipitation during the winter. Hill, Chouteau and Blaine Counties are the Transition counties and have both the chinook and continental type of climate.

Largely because of the wind influence, which in turn derives from the mountain ridge on the western boundary, low temperature extremes here have not been as cold as one might expect, but on the other hand, really hot weather is rare. The temperature varies according to elevation and according to latitude. At the higher elevations and higher latitudes the temperature is lower. The annual average temperature in the Study Area varies from 39° in Babb to 46° at Fort Benton. High temperatures on record vary from 96° to 112°; low temperatures from -32° to -59°.

The growing season, or 32° freeze-free season, generally averages between 110 and 120 days in the agricultural regions of most of the Study Area. However, some of the high plateau regions in Glacier County have a growing season of less than 90 days. The Milk River valley downstream from Fresno Dam tends to have slightly longer growing seasons, ranging from 120 to 135 days. Similarly, areas in the southern part of Chouteau County can normally expect a freeze-free season of about 130 days.

Precipitation in the Study Area averages a little less than 13 inches per year, with anywhere from 70 to 85 percent occurring during the warmer half of the year. The only notable departures from this average occur in the mountains on the western end of the Study Area where the annual precipitation is as high as 40 inches. On the other hand, some of the eastern portion gets only about 8 inches annually.

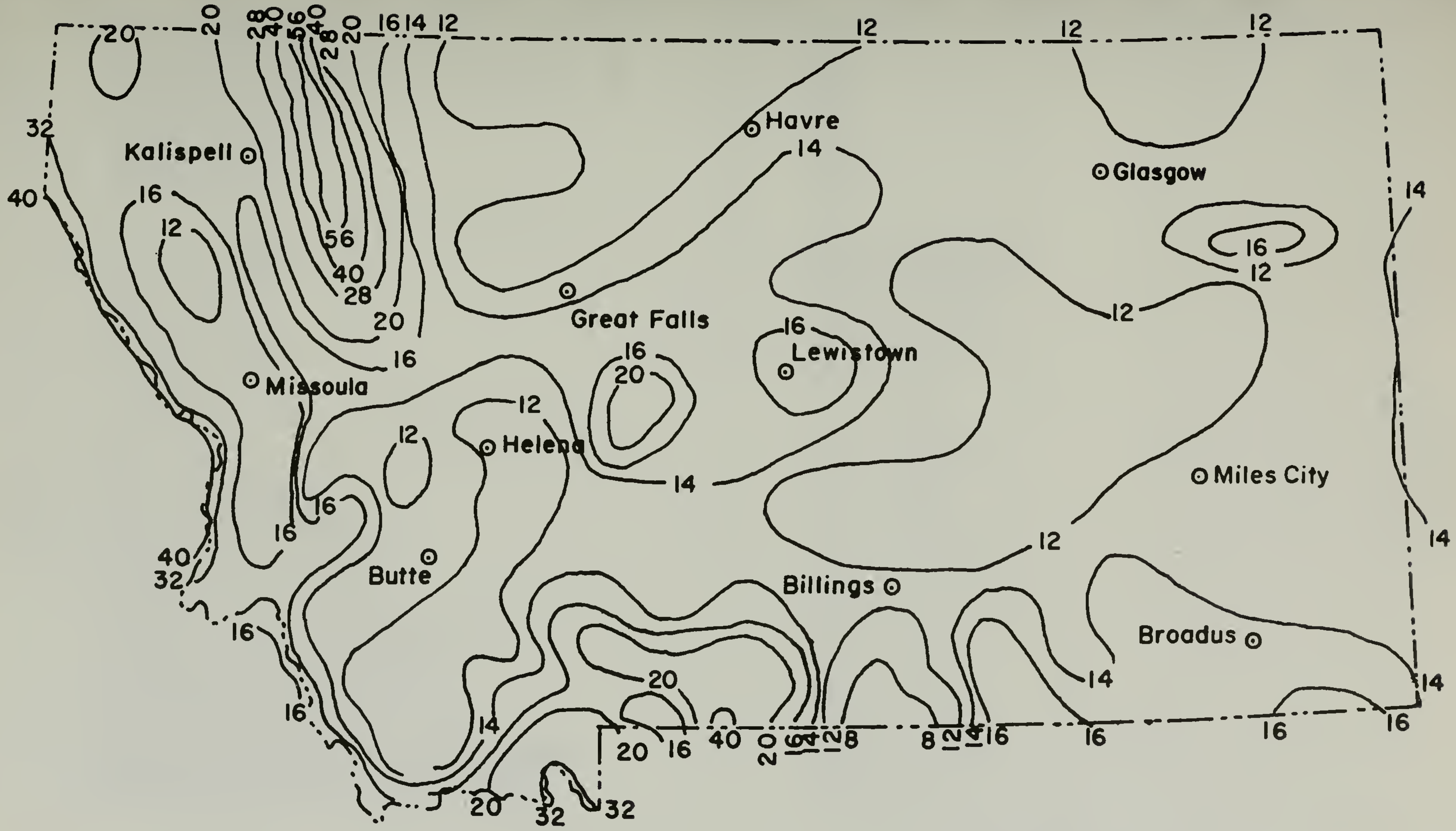
Isopuvials of mean annual precipitation for Montana are shown in Figure II-2.

Stormy weather of several kinds is observed on occasion within the Study Area. In decreasing order of economic importance, these storm types appear to be hail and thunderstorms, high winds (including winter blizzards), and heavy rains. Tornadoes have been infrequent and minor in intensity. Hail occasionally will cause damage to growing or ripening crops, but hail damage usually affects only small areas in any one year.

4. Geologic Conditions. The Study Area is characterized by the rugged Rocky Mountains of Glacier National Park in the west, the foothills disturbed belt, broad gently sloping plains and some small volcanic mountain areas toward the east.

From very early geologic time to about 60 million years ago, the Study Area andthe whole eastern slope of the Rocky Mountains was the site of shallow seas and lowland deposition. The evidence for this is found in the limestones, sandstones and shales thereabouts. Since 60 million years before present to about a million years ago, various terrestrial formations were deposited in the form of sands and clays.

In the last one million years there has been widespread glaciation leaving behind its drift. Glacial drift is made up of rock debris varying in size from huge boulders to clay size particles. Glacial debris is found as high as about 5,000 feet above sea level in the Bear Paw Mountains. This area of the Bear Paws along with the Little Rockies and some small areas in the Sweetgrass Hills are the only places in the Study Area that escaped glaciation.



MONTANA

MEAN ANNUAL PRECIPITATION

(IN INCHES)

FIGURE II - 2

Since the last "Ice Age" there has been various erosional and depositional processes that shape the landscape. Alluvium is the deposit of these processes that is loose, unconsolidated detrital debris. Examples of alluvium would be stream gravel, talus, alluvial fans, etc.

The generalized geologic column shown in Figure VI-5 is interrupted in areas of the Sweetgrass Hills, Bear Paw and Little Rocky Mountains. In these areas molten volcanic rocks intruded up through these sedimentary formations. These formations were later eroded from these intrusion areas.

B. ECONOMIC CONDITIONS

1. Population. Historic population trends indicate a relatively unstable population since 1930. Figure II-3 shows changes in population since 1930 for each county. Although most of the area experienced a large increase in population from 1950 to 1960, the last decade brought an even larger decrease. The closing of the Air Force installation at Glasgow accounted for a large part of the total decline. However, the continuing trend toward fewer and larger farms has also been a major contributor to the declining population.

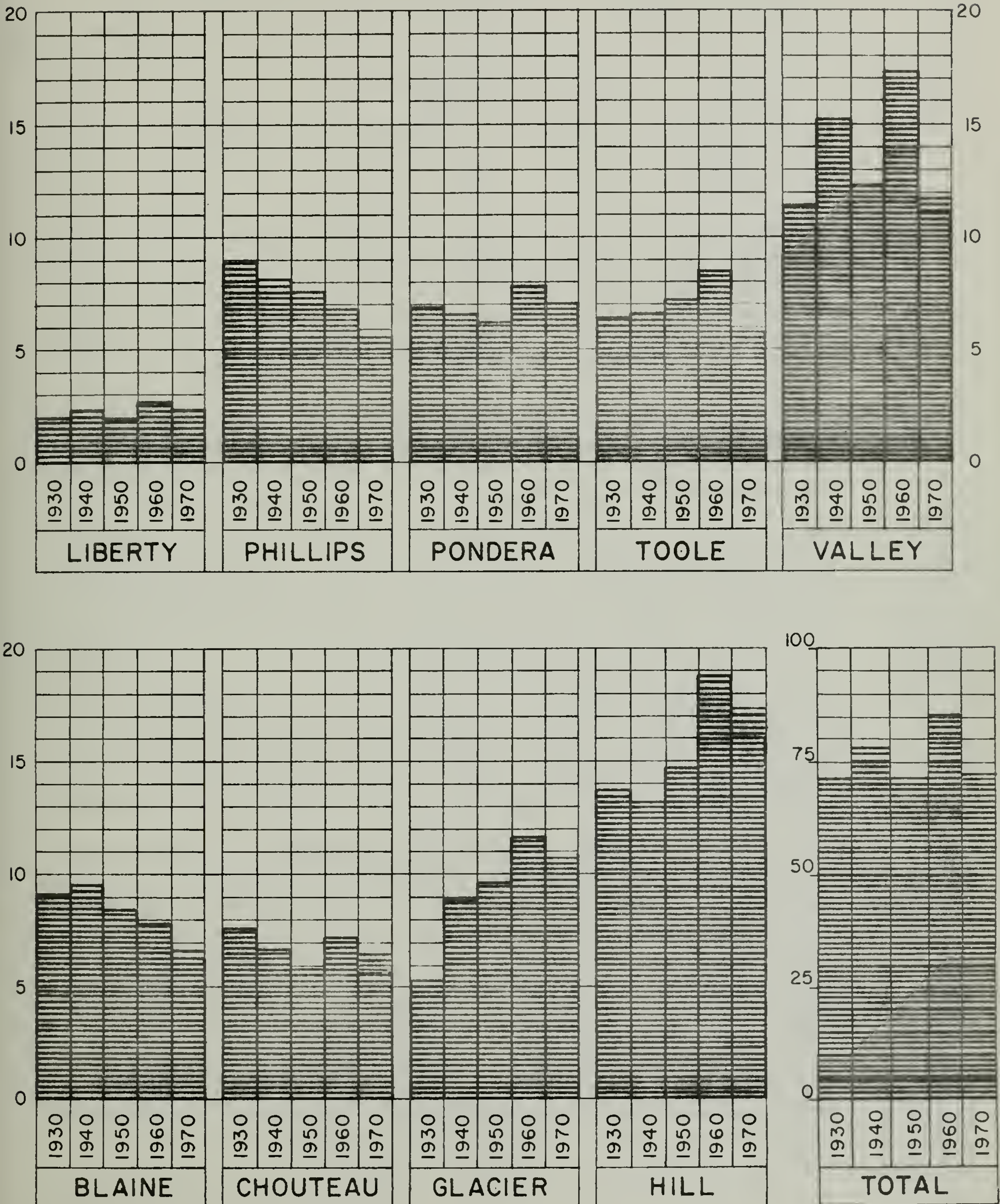
Between the 1960 and the 1970 census, the Study Area lost 13,938 persons. The 1960 census indicated 86,945 people living in the nine counties and the 1970 census indicates 73,007 people, a loss of 15.1%. Each county's change in population is as follows:[1]

County	1960 Population	1970 Population	Net Change	% Change
Glacier	11,565	10,783	- 782	- 6.8
Pondera	7,653	6,611	-1042	-13.6
Toole	7,904	5,839	-2065	-26.1
Liberty	2,624	2,359	- 265	-10.1
Chouteau	7,348	6,473	- 875	-11.9
Hill	18,653	17,358	-1295	- 6.9
Blaine	8,091	6,727	-1364	-16.9
Phillips	6,027	5,386	- 641	-10.6
Valley	17,080	11,471	-5609	-32.8

Age distribution of the population parallels closely that for the State. Only about 40 percent of the population is between 25 and 65 years old which means that the major work and tax burden rests on a minority of the population. This unbalanced situation results from a net outmigration of many young people seeking employment combined with a large retirement population.

Numbers refer to footnotes located at the end of this chapter

FIGURE II-3
POPULATION TRENDS 1930 - 1970
(In Thousands)



Source: 1970 CENSUS OF POPULATION

This out-migration is clearly spelled out and identified by the Upper Midwest Economic Study paper number 4.[2] This report indicates that the counties of the Study Area generally experienced significant out-migration in the time period 1950 to 1960. The counties and their respective net-migration ratios are as follows:

Blaine	-21.21	Chouteau	-11.45
Glacier	- 8.30	Hill	+ 1.73
Liberty	- 4.70	Phillips	-19.85
Pondera	-14.57	Toole	-15.27
Valley	+13.46		

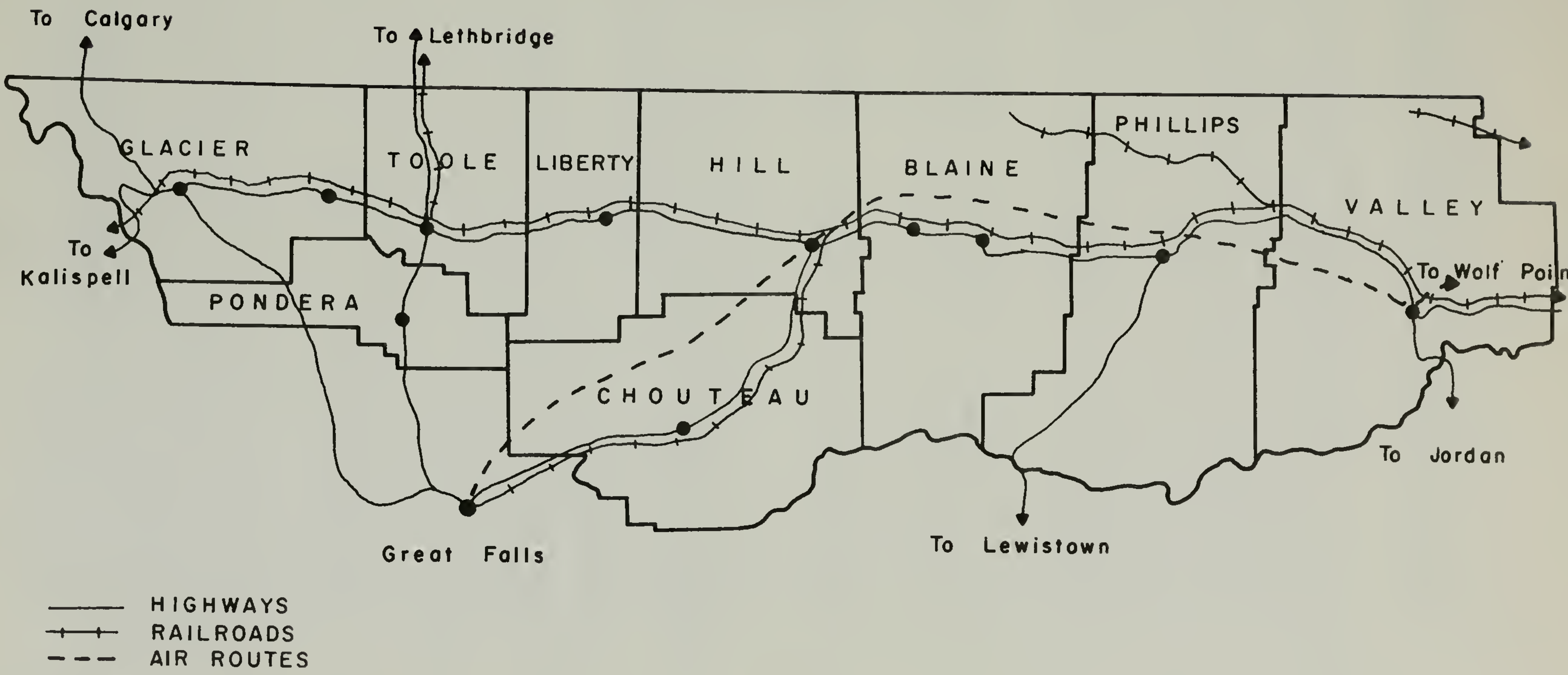
A negative migration rate of 21.21 such as that recorded for Blaine County for 1950-1960 says that the net out-migration from the county in that time period was over 21 percent. The only counties in the Study Area which showed a net in-migration were Hill and Valley Counties for this same time period. The large net in-migration to the area was in Valley County, but this trend is sharply reversed in the 1960-1970 period due to the closure of the Glasgow Air Force Base which was increasing in importance as an employment unit in Valley County in the period 1950-1960. The dependency ratio or the proportion of the total population under 15 and over 65 years old also went up significantly for each county in the time period 1950-1960.

Detailed data is not yet available from the 1970 census to evaluate these migration rates for the 1960-1970 period, but the total population recorded for these counties in 1970 would suggest that there was a continued sharp net out-migration of people for most of the counties in the Study Area 1960-1970.

It should not be forgotten that over ten percent of the Study Area population is Indian. The Indian population is centered in Blaine County on the Fort Belknap Reservation and in Glacier County on the Blackfeet Indian Reservation. This Indian population will necessarily become an increasingly important part of the area economy.

2. Transportation System. Figure II-4 shows the Study Area's transportation system. Highways are generally good throughout the area, although much of the area is inaccessible by paved highways. U.S. Highway No. 2 runs east-west through the center of the Study Area from Glasgow to Browning, passing through all the counties in the Study Area except for Chouteau and Pondera. Interstate Route 15 and U.S. Highway 91 run from Great Falls into Alberta Province in Canada through Pondera and Toole Counties. U.S. Highway 87 runs southwest from Havre to Great Falls through the south-central portion of Hill County and through Chouteau County. The area's population is concentrated heavily along U.S. Highway No. 2. Railroad

HIGHWAY RAILROAD AND AIR TRANSPORTATION IN STUDY AREA



Source:
Montana Railway map, McGill-Warner Co. St. Paul, Minn.
Montana Highways, Montana State Highway Commission, Helena, 1970
Air Traffic Schedules, Frontier Airlines, November 1970

FIGURE II-4

service generally parallels the highway service with the exception of a branch line which runs into northern Blaine County. Air service is very limited serving only Havre and Glasgow.[3]

3. Employment and Economic Influences. Employment in the area is largely agricultural. Thirty percent of the total labor force is employed on farms and a large part of the remaining work force is employed in businesses which serve the agricultural economy.[4] Income distribution in the area is similar to that of the State with 23.6 percent of the households earning less than $3,000 and 20.8 percent earning more than $10,000.[5] The culture of the area is highly oriented toward the soil and climate. Either ranching or farming exerts a great deal of influence upon the social and business life throughout the area. Climate plays an important role particularly in the western end of the Study Area in the Browning area.

There is a minimum of influence from industry upon the economy of the area. The main economy influences from areas other than agricultural employment are due to the oil industry, tourism, the presence of a college in Havre, and a minor amount of mining in the area.

The agricultural and non-agricultural economy of the area is discussed in more detail in Part IV of this report: Economy of Study Area.

4. Mineral Resources. The mineral resources in the Study Area consist of small concentrations of metallic areas and some extensive deposits of natural gas and crude oil in the westerly portion of the area. Minimal amounts of copper, gold, silver, lead, zinc and iron are present, but not in commercial quantities. Some coal, bentonite, oil and gas exist in commercial quantities but the remainder of the minerals are not expected to contribute to the economy of the area.

Natural gas is produced commercially from the Bowdoin gas field. There has been little exploratory drilling over much of the area. Considering the sparse exploratory drilling, the petroleum potential has hardly been tested.

Cretaceous and Mississippian rocks have produced commercial quantities of oil in the western part of the area. Older beds may also prove productive in the future.

Bentonite is a variety of sedimentary rock that is composed of a specific clay (montmorillonite) which has been formed by the alteration of volcanic ash. Although bentonite has a wide variety of uses, most of the interest in these deposits is in connection with taconite pelletizing. Bentonite occurs within numerous beds within the Bearpaw Shale.

Minor seams of subbituminous coal are present in the Judith River and Fort Union formations, but commercial development is not anticipated.

Some of the mineral resources and the counties in which they occur are shown as follows:

Mineral	County								
	Glacier	Pondera	Chouteau	Liberty	Toole	Hill	Blaine	Phillips	Valley
Titaniferous Magnetite	x	x							
Copper	x			x					
Gold	x			x	x			x	
Sodium Sulfate			x						
Lead				x	x				
Zinc				x					
Iron				x	x				
Niobium						x			
Bentonite	x			x	x	x	x	x	x
Gravel	x	x						x	x
Oil	x	x	x	x	x	x	x		
Coal		x	x			x			x
Fluoride				x					
Vermiculite						x			
Natural Gas	x	x	x	x	x	x		x	x

5. Recreation. The State of Montana, through its Fish and Game Commission, has developed a Statewide Outdoor Recreation Plan. The purposes of this plan are:

(1) To institute long-range planning to protect the relatively fragile physical environment while maximizing the enjoyment of participants in outdoor recreation;

(2) To provide broad guidance in development and implementation of Montana's outdoor recreation programs, and

(3) To focus attention on the recreational responsibilities of the various public agencies at the federal, state, county and community levels, as well as those of private enterprise.

The Statewide Outdoor Recreation Plan is broad in scope and is oriented to the present and to the future, with a special emphasis on the long-range view. It is a general plan, concentrating upon the more significant trends and needs and upon the policies devised to guide development of recreational facilities. Recommendations are presented to guide the developments of all agencies in reaching the goal of adequate and appropriate outdoor recreation opportunity.

The Bureau of Outdoor Recreation has developed a classification system for assessing types of activity demands and for determining the kind of natural resource areas which are necessary to provide for this demand.

Class I - High Density Recreation Areas

This class includes sites of intensive development such as are found in urban parks and comparable areas of particularly heavy use.

Class II - General Outdoor Recreation Areas

This class includes the broadest range of activities and consequently involves a wide variety of resources for the supply. Typical areas range from the larger urban parks to state parks and recreation areas. Certain developed portions of forest lands may also be included. Activities take place in a more spacious setting and the natural environment is a major factor in the recreation experience.

Class III - Natural Environment

For purposes of this classification, natural environment is defined as those vast undeveloped areas providing for multiple uses including recreation.

Class IV - Outstanding Natural Areas

The State Fish and Game Commission, through the Recreation and Parks Division, provides several outstanding natural areas throughout the State.

Class V - Primitive Areas

This class is made up of undisturbed roadless areas, characterized by natural wild conditions including wilderness.

Class VI - Historic and Cultural Sites

The State Fish and Game Commission has been designated as the official State Agency in matters of historic preservation and appropriate interpretation of features of historic significance.

A local inventory of outdoor recreational land and facilities is given in Tables II-1 and II-2.[6] This local inventory includes only county and municipal facilities; state and national facilities have not been inventoried. The inventory of outdoor recreational land shown in Table II-1 gives the acreages in each of the Bureau of Outdoor Recreation classes listed above. Class 4 and 5 do not appear in the table because no BOR Class 4 or 5 land was reported by local

governments. The bottom half of Table II-1 and Table II-2 gives the acreage in various types of recreational facilities and the type and number of units at the sites.

Demand estimates for outdoor recreation activities and facilities were made as a part of the Statewide Outdoor Recreation Plan. Twenty-five outdoor recreation activities were considered and the number of activity days were estimated for each of these activities for residents and non-residents for the years 1970, 1975 and 1985. The estimates for 1970 and 1985 are shown in Tables II-3 and II-4.[7]

Of the twenty-five outdoor activities considered in the Statewide plan, those which could have the most significant impact on the area are those which would tend to attract non-residents to the area for recreation, such as hunting, fishing, camping, boating, and snowmobiling. Experience in other areas of the country indicate that when people travel to an area to recreate, they spend a generous amount of money per capita which adds to the economy of the area.

Another source of valuable information on recreation in the area is contained in a series of reports on the appraisal of potential outdoor recreational developments prepared by county technical action panels from the various counties. The technical action panels were generally composed of local people from the Soil Conservation Service, Cooperative Extension Service, State Fish and Game Department, Farmers Home Administration, Bureau of Indian Affairs, County Commissioners, and the Agricultural Stabilization and Conservation Service.

Potential Recreation Development Reports were available for Valley, Phillips, Blaine, Toole, Chouteau, and Pondera Counties. In these reports, the potential for twelve kinds of recreational developments were examined separately.

The twelve kinds of recreation development and subdivisions that were evaluated are:

1. Vacation Cabins, Cottages, and Homesites
2. Camping
   a. Vacation Site
   b. Pack Trip
   c. Transient
3. Picnic and Sports Areas
   a. Game, play, target areas
   b. Bicycling
   c. Picnicking

4. Fishing Waters
    a. Warm water
    b. Cold water

5. Golf Courses
    a. Standard and par-3
    b. Miniature and driving ranges

6. Hunting Areas
    a. Small game
    b. Big game
    c. Water fowl

7. Natural, Scenic and Historic Areas
    a. Natural areas
    b. Scenic areas
    c. Historic areas

8. Riding stables

9. Shooting Preserves

10. Vacation Farms and Ranches
    a. Farms
    b. Ranches

11. Water Sports Areas

12. Winter Sports Areas

Each of these types of recreational development had different criteria for evaluation, depending upon the requirements of the activities involved. A point rating system was used which considered the effects of climate, fish and wildlife habitat and population, existing and potential water development sites, population and income distribution, soils, proximity and access, land ownership and use, and scenic, natural and historic areas.

Based on these appraisals for the six counties for which reports were available, the recreational developments with the most potential for development in the Study Area include hunting of all types, boat and transient camping, and natural, scenic, and historical areas. A summary of the appraisals of potentials for outdoor recreation development as reported by the six county technical action panels is given in Table II-5 .

TABLE II-5

SUMMARY OF APPRAISALS OF POTENTIALS FOR OUTDOOR RECREATION

	Kinds of Recreation Development		Valley Co.	Phillips Co.	Blaine Co.	Toole Co.	Chouteau Co.	Pondera Co.
I	Vacation Cabins, Cottages and Homesites		M	M	M	-	M	M
II	Camping	Vacation Site	M	M	M	-	M	M
		Boat Trip	M	M	H	-	H	H
		Transient	H	M	H	M	M	M
III	Picnic and Sports Area	Game & Play Area	M	L	L	-	-	-
		Bicycling	-	-	-	-	-	-
		Picnicking	M	L	M	M	-	M
IV	Fishing Areas	Warm Waters	M	M	-	-	-	-
		Cold Waters	M	L	M	M	H	M
V	Golf Course	Std. & Par-3	-	-	-	-	M	-
		Min. & Dr.Rg.	-	-	-	-	M	-
VI	Hunting Areas	Small Game	M	M	H	L	H	H
		Big Game	M	M	H	M	H	M
		Water Fowl	H	M	H	M	M	M
VII	Natural, Scenic & Historic Areas	Natural Areas	H	M	H	M	H	M
		Scenic Areas	H	M	H	M	H	M
		Historic Areas	M	H	H	M	H	M
VIII	Riding Stables		-	-	-	-	-	-
IX	Shooting Preserves		-	-	-	-	-	-
X	Vacation Ranches		-	M	-	-	M	M
XI	Water Sports Areas		M	M	-	L	M	L
XII	Winter Sports Areas		-	-	-	-	M	-

H - High potential
M - Medium potential
L - Low potential
- - Not rated

Source: Technical Action Panel Reports

FOOTNOTES - PART II

1 Source: Census of Population, U. S. Department of Commerce, 1960 & 1970 data.

2 Borchert, John R. and Russel B. Adams, Trade Centers and Trade Areas of the Upper Midwest, Urban Report Number 4, Upper Midwest Economic Study, September 1963.

3 Air traffic schedules, Frontier Airlines, November 1970.

4 Census of Agriculture, 1964, Montana Bureau of the Census, U. S. Dept. of Commerce, pp. 258-263.

5 County and City Data Book, 1967, Bureau of the Census, U. S. Dept. of Commerce, pp. 213, 223.

6 Tables II-1 and II-2 are located at the end of this report in Appendix I.

7 Tables II-3 and II-4 are located at the end of this report in Appendix I.

PART III - PROJECT LANDS

PART III

PROJECT LANDS

A. INTRODUCTION

The soils of the Study Area can be divided into five categories according to the soil forming process:

1. Continental glacial soils formed as a result of ice during the glacial period.

2. Alluvial soils formed by streams during ancient and recent times.

3. Residual soils formed from material weathered from geological formations.

4. Mountain glacial soils which were deposited in recessional ridges of mountain glaciers.

5. Lacustrine soils formed from sediments that have settled out of quiet waters - in this case from glacial lakes and ponds.

Local rock formations furnish the material for soils found in a given area. The physiography, drainage, and geologic history have an influence on how these materials were deposited and account for many of the differences found in soils. Soil depth, texture, and acidity or alkalinity are directly related, within limits, to the material from which the soil is formed.

The variations in soils result from the various stages of alteration of geologic material through the action of wind and water, and the effects of vegetation and living organisms. The length of time these forces have been active is particularly influential in causing visible soil differences.

Topography also plays an important role in determining the suitability of land for various uses. Except for the Rocky Mountains along the western edge of Glacier and Pondera counties, the Sweetgrass Hills, the Little Rocky Mountains and the Bearpaw Mountains, the Study Area is mostly rolling terrain and benchlands. The gently rolling to rolling terrain is typical of areas covered by continental glaciers. Most of the Study Area falls into this category. There are, however, large benches of fairly flat land in Valley, Phillips, Blaine and Glacier counties. The benchlands in the Study Area had very thin glacial ice cover and escaped the remolding of topography associated with a thicker glacial covering. A narrow strip of badland areas is located in the river break area north of the Missouri River. The significance of these badland areas for irrigation planning is essentially nil. Alluvial valleys are found along the Milk and Marias Rivers and along the Missouri River below Fort Peck. There are also alluvial valleys along most of the areas tributaries.

A third area of interest in determining the suitability of land for irrigation potential is drainability. Drainage is a restricting factor for a large acreage of the area. In many areas the till substratum is at a shallow depth which prevents adequate downward movement of the water. In other areas heavy textured soils such as the Bowdoin clays make drainage very difficult. Drainage and other limiting factors are discussed in more detail in the following paragraphs.

B. SOIL SURVEYS AND CLASSIFICATION

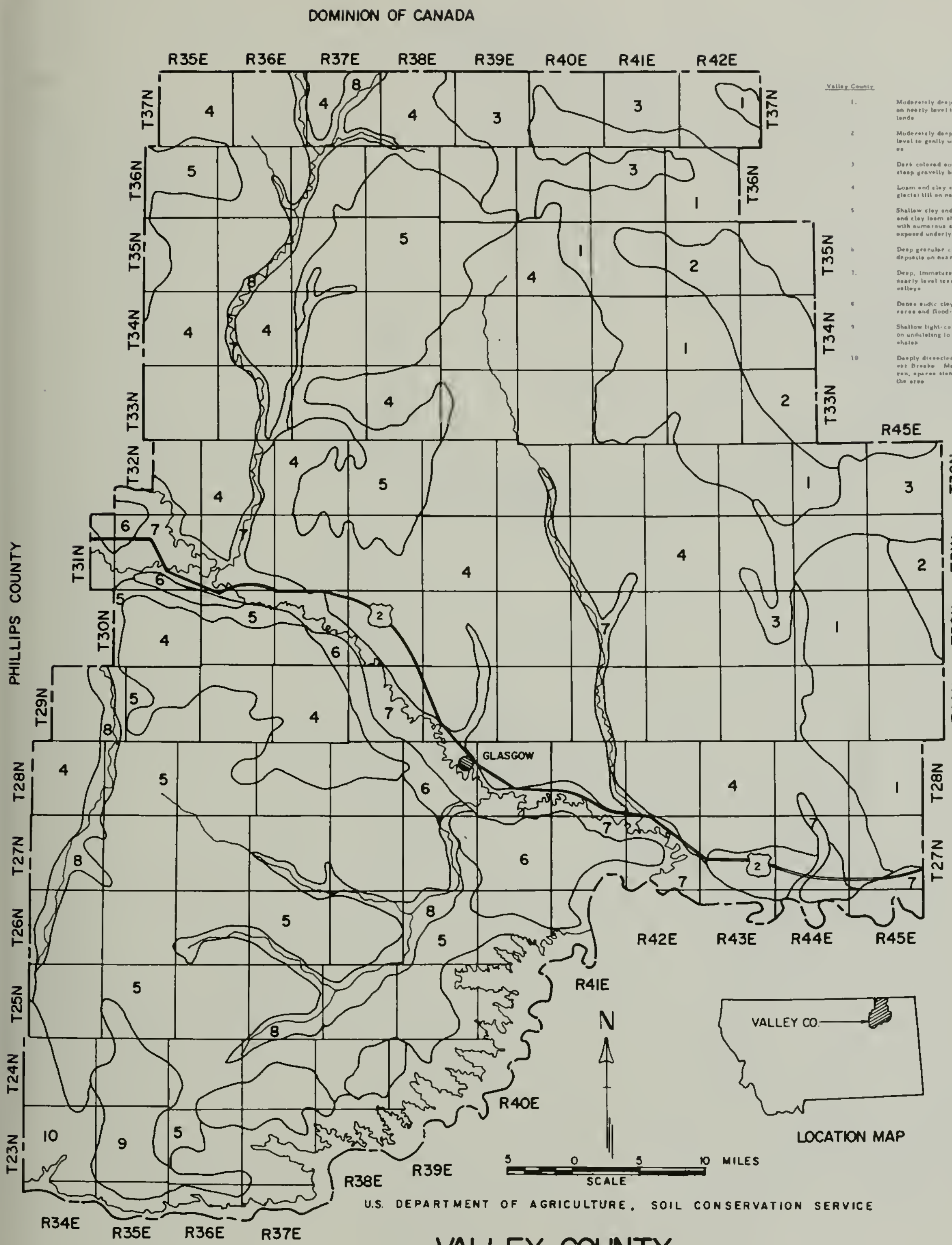
Soil surveys are made cooperatively by Federal and State agencies. Soil scientists map and sample soils in the field, test them in laboratories and correlate and record the findings. Soil maps and soil survey interpretations are available at Soil Conservation Service, Montana Agricultural Experiment Station and Extension Service offices.

General soils maps have been completed by the Soil Conservation Service for each of the nine counties. Detailed soil maps and reports of the soil surveys are presently being prepared for Glacier, Blaine and Valley counties. The detailed survey in Glacier has been completed and the information is available from the SCS even though the report will not be available in final published form before 1972; the survey in Blaine is presently 60% to 70% complete; Valley will not be complete before 1975. Detailed soil surveys in the other counties have not yet begun.

General soil maps for each of the nine counties are included in this section of the report. The general soil maps, as the name implies, are quite general in nature and include only broad grouping according to their dominant characteristics.

C. LAND CLASSIFICATION AND DESCRIPTION

Land classification is the systematic appraisal of lands and their designation by categories on the basis of similar characteristics. The Water Resources Board land classification surveys are conducted for the specific purpose of establishing the extent and degree of suitability of lands for sustained irrigation farming. The objective of the survey is to outline the land areas that have a future potential for irrigated agriculture to the ultimate in year 2020. Technological advances in irrigation are considered in this report. The slope and surface topography become less important because of the rapid expansion of sprinkler irrigation throughout the Western States.



Valley County

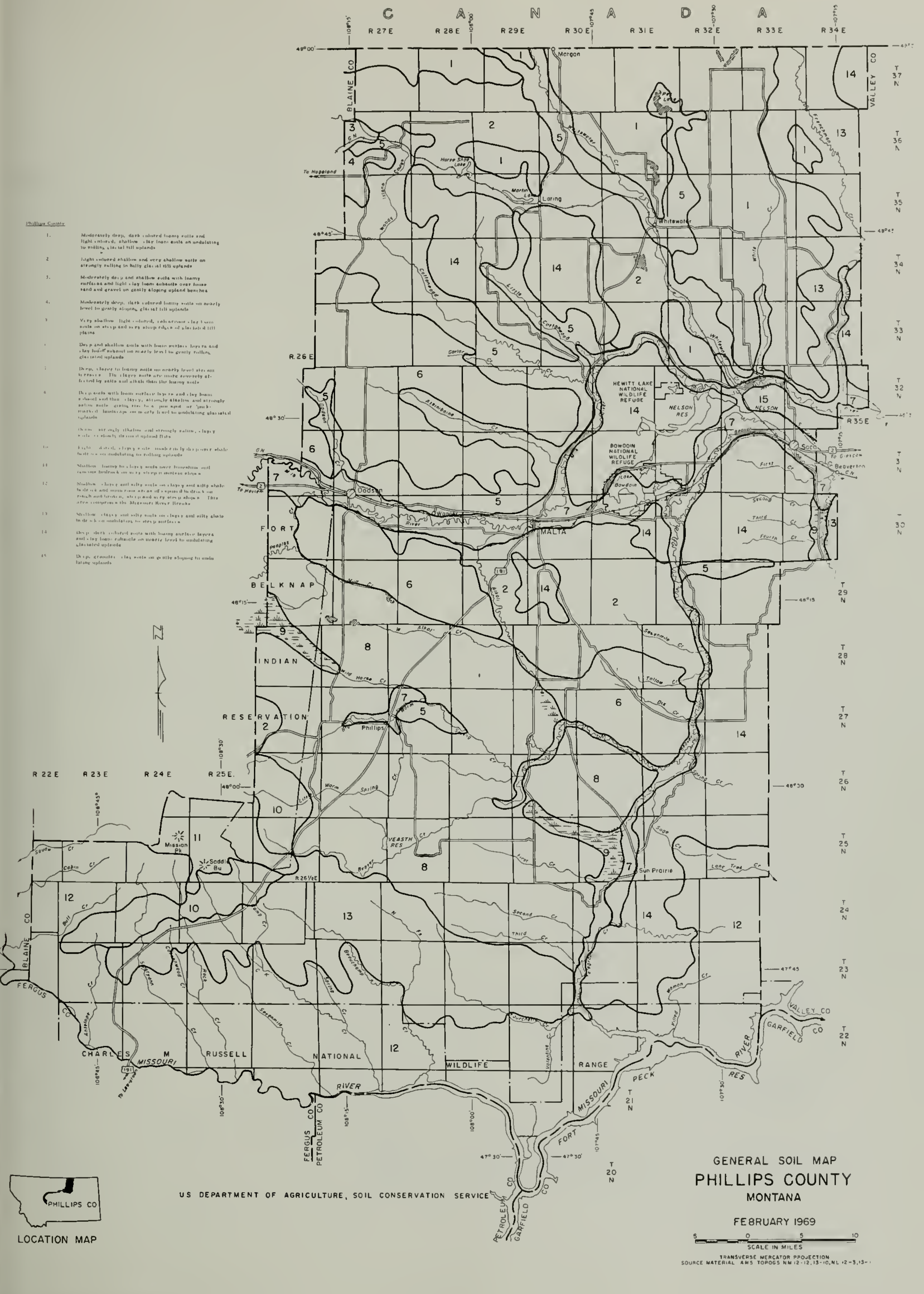
1. Moderately deep and very shallow dark colored soils on nearly level to moderately steep glaciated uplands
2. Moderately deep dark-colored sandy loams on nearly level to gently undulating surfaces on old high benches
3. Dark colored soils developed on moderately steep to steep gravelly bench edges and silty shale beds
4. Loam and clay soils developed in heavy clay loam glacial till on nearly level to undulating uplands
5. Shallow clay and clay loam soils developed in clay and clay loam shales on undulating to steep topography with numerous areas where geologic erosion has exposed underlying shale beds
6. Deep granular clay soils developed in thick clayey deposits on nearly level to gently undulating uplands
7. Deep, immature clay loam, clay and loam soils on nearly level terraces and flood plains in stream valleys
8. Dense sodic clay soils developed on nearly level terraces and flood-plains in stream valleys
9. Shallow light-colored silty and sandy soils developed on undulating to steep topography in silty and sandy shales
10. Deeply dissected areas comprising the Missouri River Breaks. Many steep side slopes are nearly barren, sparse stands of timber cover some portions of the area

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE

VALLEY COUNTY

GENERAL SOIL AREA MAP

AUGUST 1967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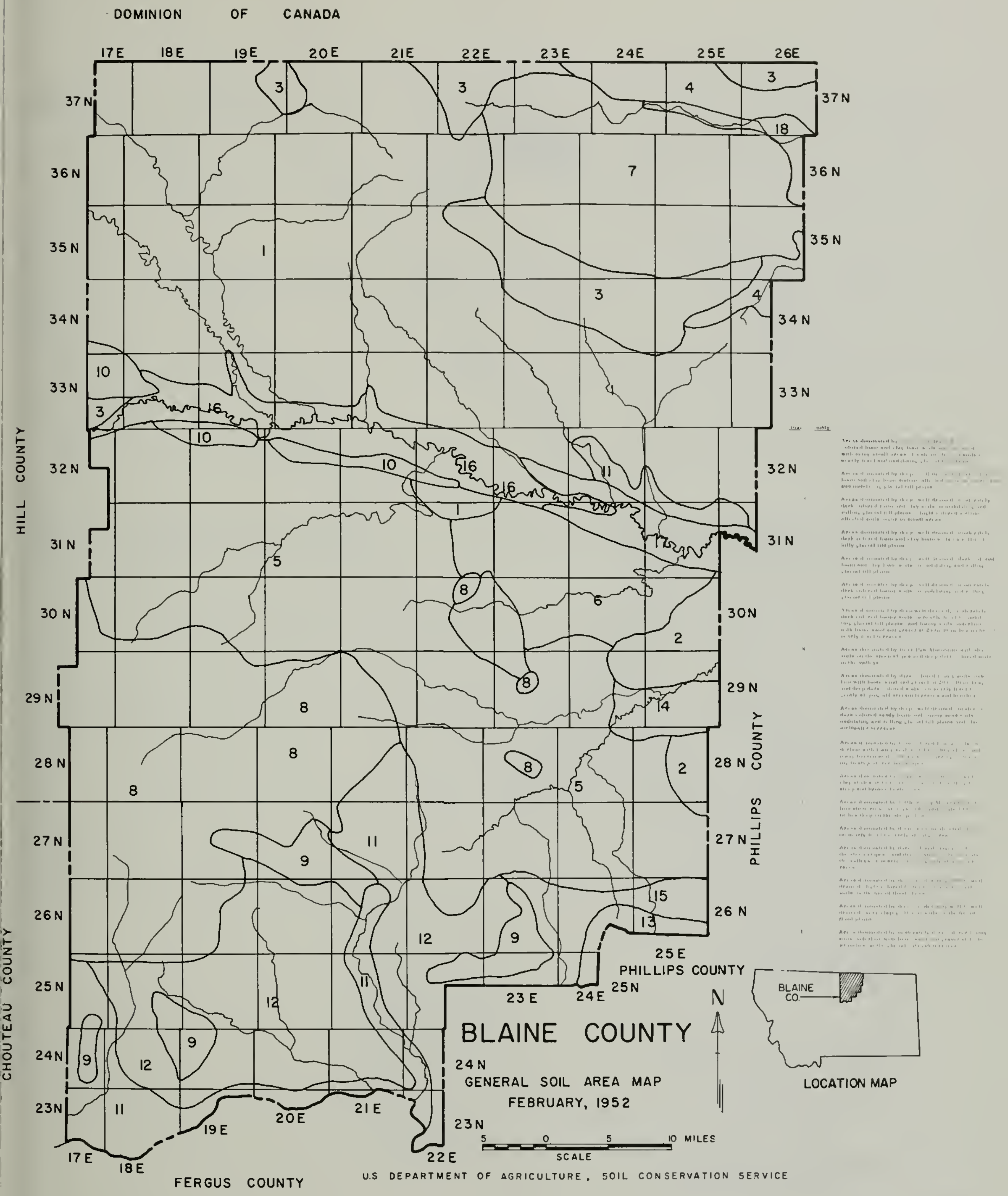
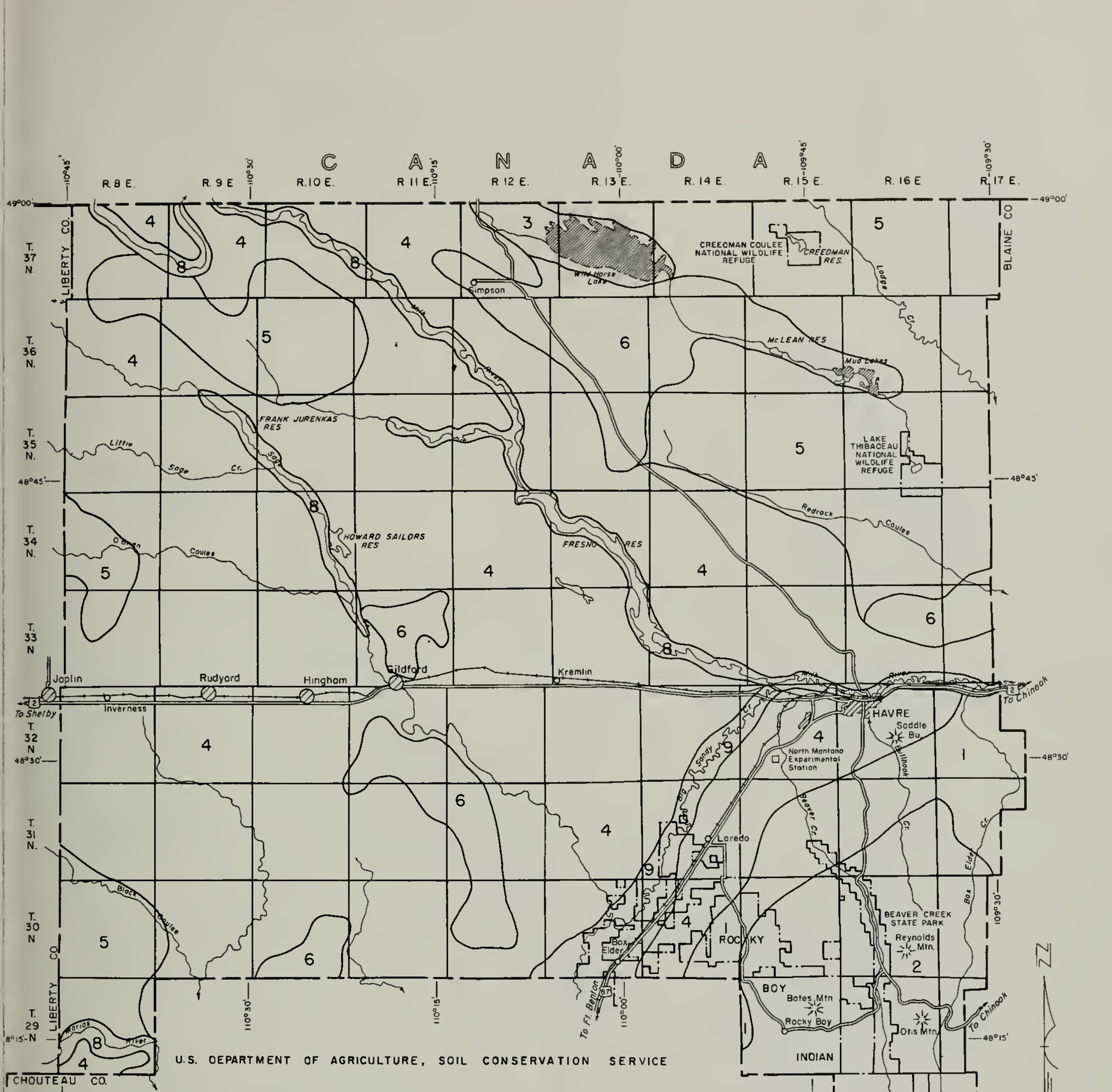
BLAINE CO
VALLEY CO
FERGUS CO
PETROLEUM CO
GARFIELD CO
Morgan
Loring
Whitewater
Dodson
Malta
Saco
Phillips
Sun Prairie
To Nagaland
To Havre
To Glasgow
To Lewistown
Beaverton
HEWITT LAKE NATIONAL WILDLIFE REFUGE
NELSON RES
BOWDOIN NATIONAL WILDLIFE REFUGE
FORT BELKNAP INDIAN RESERVATION
CHARLES M RUSSELL NATIONAL WILDLIFE RANGE
MISSOURI RIVER
FORT PECK RES
Mission Pk
Saddle Bu
VEASTH RES
Phillips County
1. Moderately deep, dark colored loamy soils and light colored, shallow clay loam soils on undulating to rolling glacial till uplands
2. Light colored shallow and very shallow soils on strongly rolling to hilly glacial till uplands
3. Moderately deep and shallow soils with loamy surfaces and light clay loam subsoils over loose sand and gravel on gently sloping upland benches
4. Moderately deep, dark colored loamy soils on nearly level to gently sloping glacial till uplands
GENERAL SOIL MAP
PHILLIPS COUNTY
MONTANA
FEBRUARY 1969
SCALE IN MILES
TRANSVERSE MERCATOR PROJECTION
US DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE
PHILLIPS CO
LOCATION MAP


DOMINION OF CANADA
HILL COUNTY
CHOUTEAU COUNTY
PHILLIPS COUNTY
FERGUS COUNTY
17E 18E 19E 20E 21E 22E 23E 24E 25E 26E
37N 36N 35N 34N 33N 32N 31N 30N 29N 28N 27N 26N 25N 24N 23N
BLAINE COUNTY
GENERAL SOIL AREA MAP
FEBRUARY, 1952
N
5 0 5 10 MILES
SCALE
BLAINE CO.
LOCATION MAP
U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE



Hill County

1. Deep, well drained, dark colored, loam and clay loam soils on undulating to rolling glacial till plains

2. Areas dominated by shallow soils in Bear Paw Mountains with deep, dark colored loam soils in valleys and on outwash terraces and fans

3. Areas dominated by poorly drained clay soils on level old lake beds

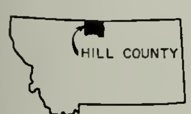
4. Areas dominated by well drained, moderately dark colored loam and clay loam soils on undulating to rolling glacial till plains and nearly level glacial meltwater terraces. Light colored soils with crusty surfaces are scattered throughout in areas of less than one acre to more than two hundred acres in size, and steep slopes along streamways are included.

5. Areas dominated by silt loam and silty clay loam soils on nearly level to undulating glacial till plains and glacial meltwater terraces. Light colored soils with crusty surfaces occur in areas of less than one acre to two hundred acres and more in size.

6. Areas dominated by deep, fine sandy loam and loamy fine sand soils on nearly level to rolling glacial meltwater terraces

7. Areas dominated by shallow soils on steep and rough broken topography. Deep loam and clay loam soils on fans and bottom lands are included.

8. Areas dominated by loam to clay soils affected by salinity and alkalinity on nearly level terraces.



LOCATION MAP

GENERAL SOIL AREA MAP

HILL COUNTY

MONTANA

JANUARY 1969

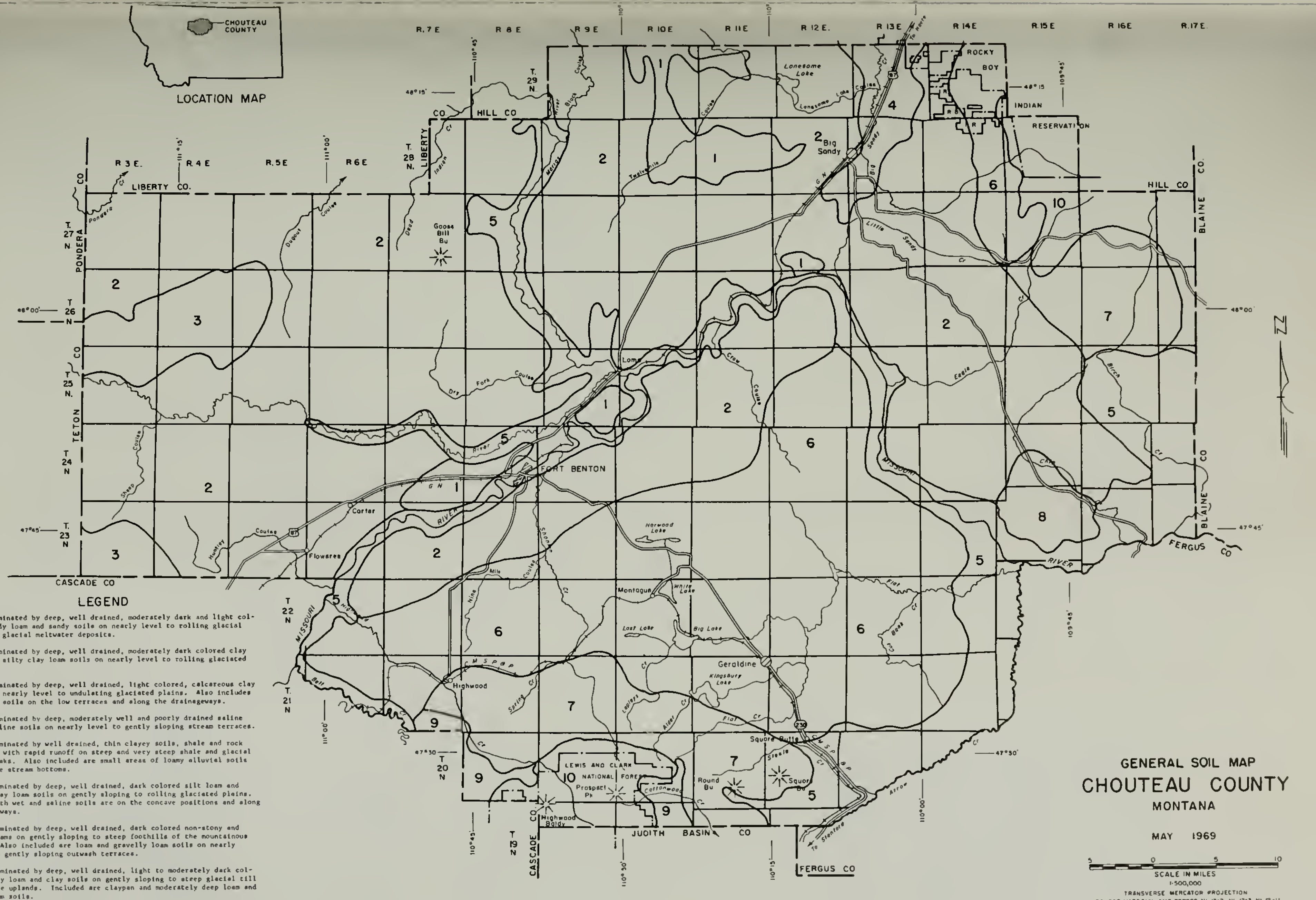
5 0 5 10 MILES

SCALE 1:250,000

TRANSVERSE MERCATOR PROJECTION

SOURCE MATERIAL: AMS TOPOGS NM 12-11, 12-12

7-0-21462



GENERAL SOIL MAP
CHOUTEAU COUNTY
MONTANA

MAY 1969

SCALE IN MILES
1:500,000
TRANSVERSE MERCATOR PROJECTION
SOURCE MATERIAL: AMS TOPOGS NL 12-2, NL 12-3, NL 12-11 AND NL 12-12

LEGEND

1. Areas dominated by deep, well drained, moderately dark and light colored sandy loam and sandy soils on nearly level to rolling glacial till and glacial meltwater deposits.
2. Areas dominated by deep, well drained, moderately dark colored clay loam and silty clay loam soils on nearly level to rolling glaciated plains.
3. Areas dominated by deep, well drained, light colored, calcareous clay soils on nearly level to undulating glaciated plains. Also includes clay pan soils on the low terraces and along the drainageways.
4. Areas dominated by deep, moderately well and poorly drained saline and alkaline soils on nearly level to gently sloping stream terraces.
5. Areas dominated by well drained, thin clayey soils, shale and rock outcrops with rapid runoff on steep and very steep shale and glacial till breaks. Also included are small areas of loamy alluvial soils along the stream bottoms.
6. Areas dominated by deep, well drained, dark colored silt loam and silty clay loam soils on gently sloping to rolling glaciated plains. Areas with wet and saline soils are on the concave positions and along drainageways.
7. Areas dominated by deep, well drained, dark colored non-stony and stony loams on gently sloping to steep foothills of the mountainous areas. Also included are loam and gravelly loam soils on nearly level to gently sloping outwash terraces.
8. Areas dominated by deep, well drained, light to moderately dark colored clay loam and clay soils on gently sloping to steep glacial till and shale uplands. Included are claypan and moderately deep loam and clay loam soils.
9. Areas dominated by moderately deep, well drained, dark colored loam to clay soils on undulating to steep shale and hard rock uplands. Also includes shallow soils on steep and rough broken slopes.
10. Areas dominated by deep and shallow, well drained loamy soils on steep to very steep mountainous areas.

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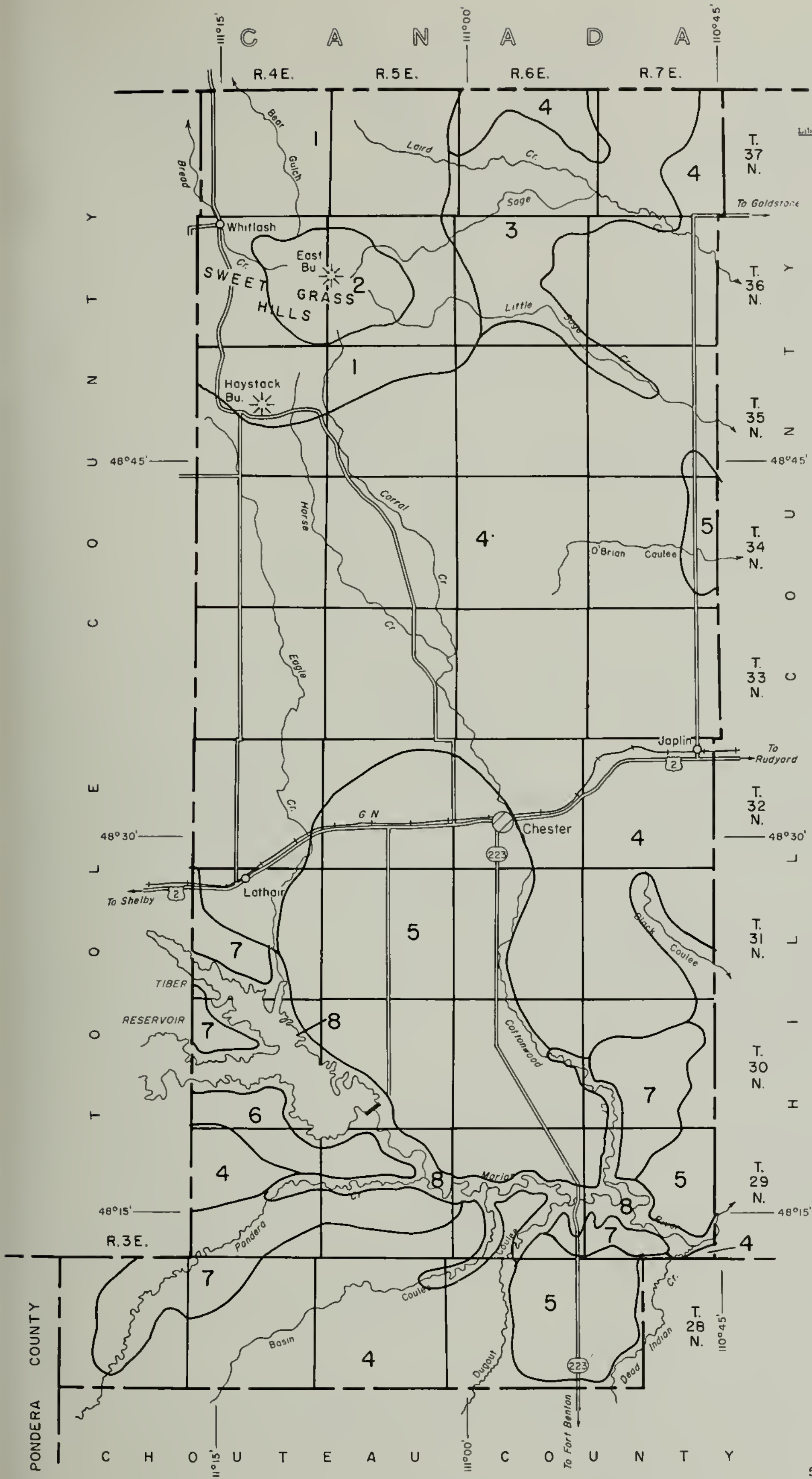


Liberty County

1. Deep, well drained, dark colored, loam and clay soils on undulating to rolling glacial till plains

2. Areas dominated by shallow soils in Sweetgrass Hills with deep, dark colored loam soils in valleys and on outwash terraces and fans

3. Areas dominated by shallow soils over bedrock on steep slopes and deep loam and clay soils on undulating and rolling glacial till plains. Deep, loamy soils on bottom lands in narrow stream valleys are included.

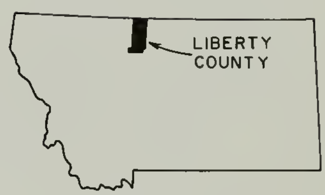
4. Areas dominated by well drained, moderately dark colored loam and clay loam soils on undulating to rolling glacial till plains and nearly level glacial meltwater terraces. Light colored soils with crusty surfaces are scattered throughout in areas of less than one acre to more than two hundred acres in size, and steep slopes along streamways are included.

5. Areas dominated by silt loam and silty clay soils on nearly level to undulating glacial till plains and glacial meltwater terraces. Light colored soils with crusty surfaces occur in areas of less than one acre to two hundred acres and more in size.

6. Areas dominated by deep, fine sandy loam and loamy fine sand soils on nearly level to rolling glacial meltwater terraces.

7. Areas dominated by well drained clay soils on nearly level to gently undulating glacial meltwater terraces.

8. Areas dominated by shallow soils on steep and rough broken topography. Deep loam and clay loam soils on fans and bottom lands are included



LOCATION MAP

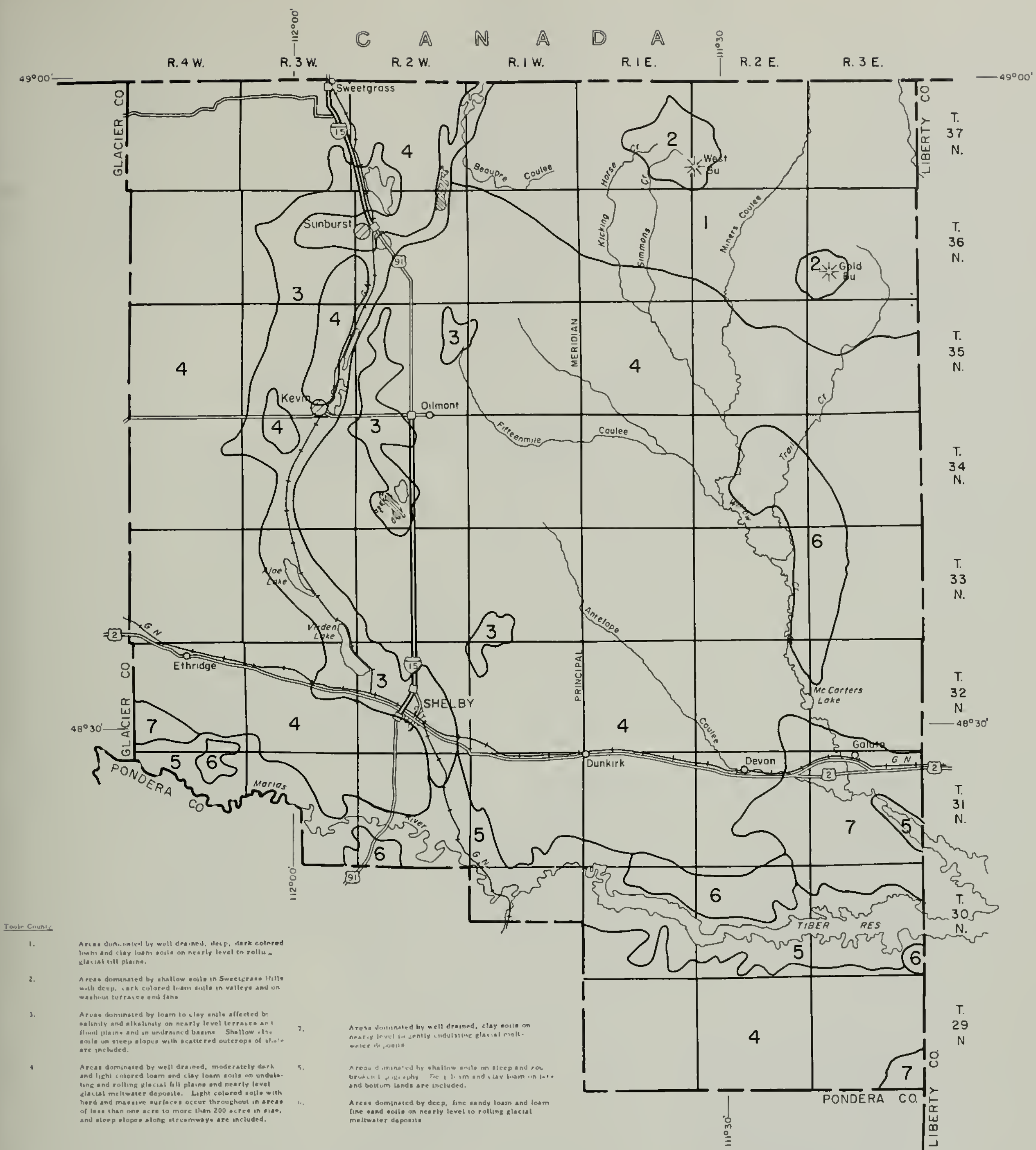
GENERAL SOIL AREA MAP
LIBERTY COUNTY
MONTANA

NOVEMBER 1969

5 0 5 10 MILES

SCALE 1:250,000
TRANSVERSE MERCATOR PROJECTION
SOURCE MATERIAL: AMS TOPOG NM 12-11

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE



U.S DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE

GENERAL SOIL AREA MAP

TOOLE COUNTY

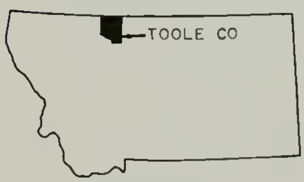
MONTANA

JUNE 1969

4 0 4 8 MILES

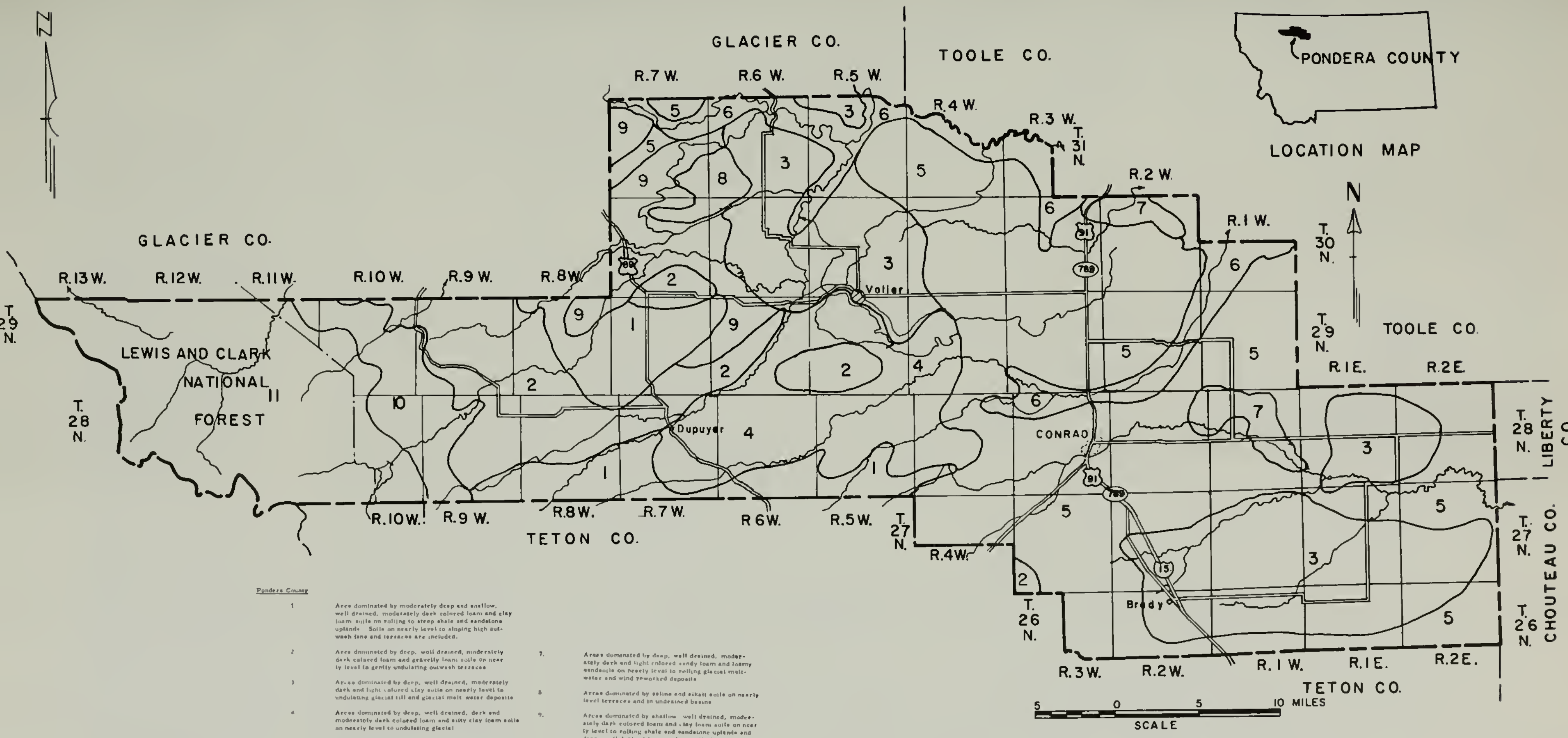
SCALE 1:250,000

TRANSVERSE MERCATOR PROJECTION
SOURCE MATERIAL AMS TOPOGS NL 12-11, 12-10



LOCATION MAP

7-0-21464



Pondera County

1 Area dominated by moderately deep and shallow, well drained, moderately dark colored loam and clay loam soils on rolling to steep shale and sandstone uplands. Soils on nearly level to sloping high outwash fans and terraces are included.

2 Area dominated by deep, well drained, moderately dark colored loam and gravelly loam soils on nearly level to gently undulating outwash terraces

3 Areas dominated by deep, well drained, moderately dark and light colored clay soils on nearly level to undulating glacial till and glacial melt water deposits

4 Areas dominated by deep, well drained, dark and moderately dark colored loam and silty clay loam soils on nearly level to undulating glacial

5. Areas dominated by deep, well drained, moderately dark and light colored loam and clay soils on nearly level to rolling glacial till and glacial melt-water deposits

6 Areas dominated by rough broken lands, consisting of shallow clay soils over shale and light colored calcareous glacial till soils. Outcrops of shale or sandstone are scattered throughout the area

7. Areas dominated by deep, well drained, moderately dark and light colored sandy loam and loamy sand soils on nearly level to rolling glacial melt-water and wind reworked deposits

8 Areas dominated by saline and alkali soils on nearly level terraces and in undrained basins

9. Areas dominated by shallow, well drained, moderately dark colored loam and clay loam soils on nearly level to rolling shale and sandstone uplands and deep, well drained loam and gravelly loam soils on nearly level to undulating outwash benches

10. Areas dominated by deep and moderately deep, well drained light and dark colored stony soils on steep foothills

11. Areas dominated by moderately deep and very shallow stony soils and igneous and limestone rock out-crops of the mountains

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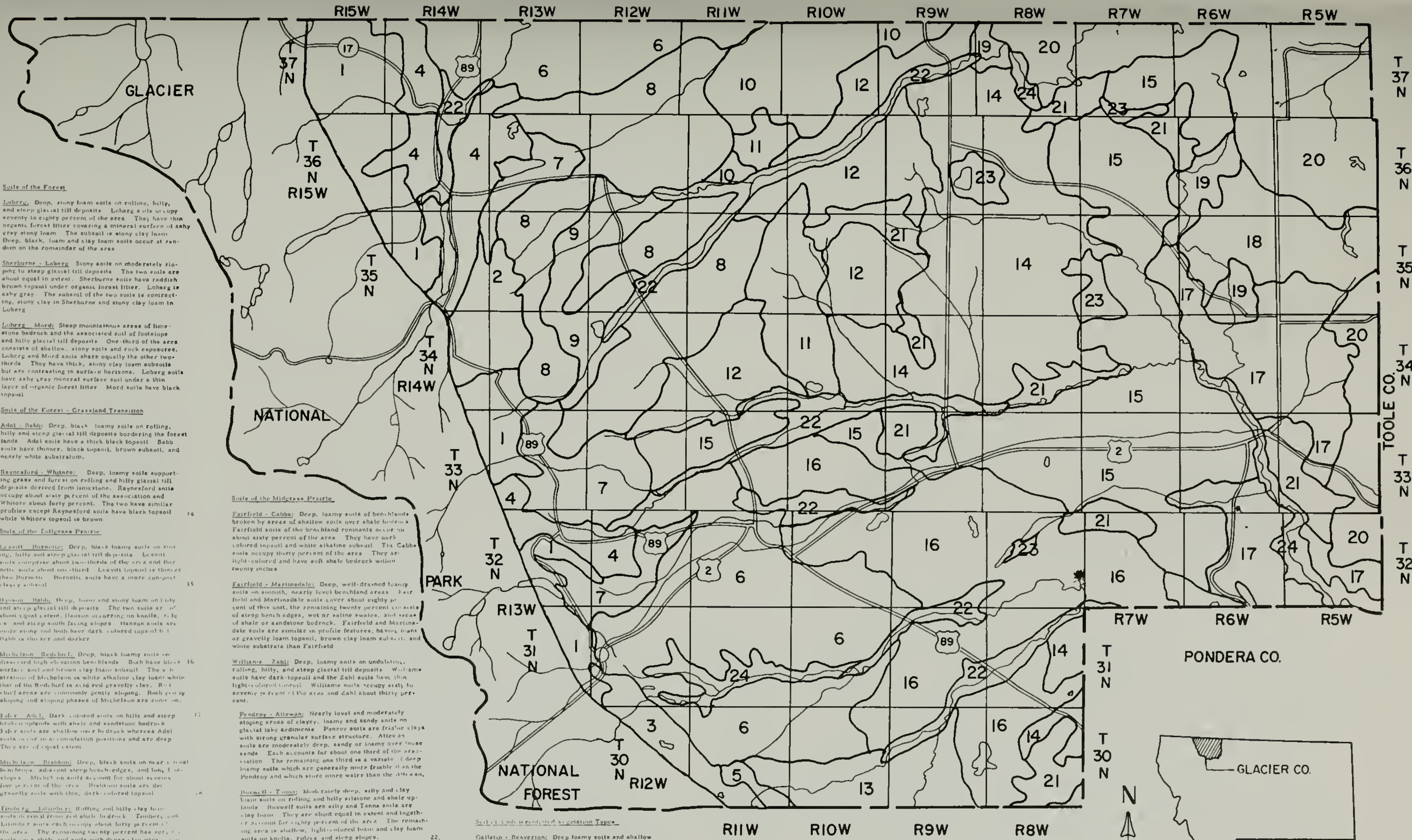
PONDERA COUNTY

GENERAL SOIL AREA MAP

SEPTEMBER 1969



GLACIER COUNTY

GENERAL SOIL AREA MAP

NOVEMBER 1969

U.S DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE

Glacier County

Soil Classification

Soils of the Forest

1. Loberg. Deep, stony loam soils on rolling, hilly, and steep glacial till deposits. Loberg soils occupy seventy to eighty percent of the area. They have thin organic forest litter covering a mineral surface of ashy gray stony loam. The subsoil is stony clay loam. Deep, black, loam and clay loam soils occur at random on the remainder of the area.

2. Sherburne - Loberg. Stony soils on moderately sloping to steep glacial till deposits. The two soils are about equal in extent. Sherburne soils have reddish brown topsoil under organic forest litter. Loberg is ashy gray. The subsoil of the two soils is contrasting, stony clay in Sherburne and stony clay loam in Loberg.

3. Loberg - Mord: Steep mountainous areas of limestone bedrock and the associated soil of footslope and hilly glacial till deposits. One-third of the area consists of shallow, stony soils and rock exposures. Loberg and Mord soils share equally the other two-thirds. They have thick, stony clay loam subsoils but are contrasting in surface horizons. Loberg soils have ashy gray mineral surface soil under a thin layer of organic forest litter. Mord soils have black topsoil.

Soils of the Forest - Grassland Transition

4. Adel - Babb: Deep, black loamy soils on rolling, hilly and steep glacial till deposits bordering the forest lands. Adel soils have a thick black topsoil. Babb soils have thinner, black topsoil, brown subsoil, and nearly white substratum.

5. Raynesford - Whitore: Deep, loamy soils supporting grass and forest on rolling and hilly glacial till deposits derived from limestone. Raynesford soils occupy about sixty percent of the association and Whitore about forty percent. The two have similar profiles except Raynesford soils have black topsoil while Whitore topsoil is brown.

Soils of the Tallgrass Prairie

6. Leavitt - Burnette: Deep, black loamy soils on rolling, hilly and steep glacial till deposits. Leavitt soils comprise about two-thirds of the area and Burnette soils about one-third. Leavitt topsoil is thinner than Burnette. Burnette soils have a more compact clayey subsoil.

7. Hanson - Babb: Deep, loam and stony loam on hilly and steep glacial till deposits. The two soils are of about equal extent, Hanson occurring on knolls, ridges and steep south facing slopes. Hanson soils are more stony and both have dark colored topsoil but Babb is thicker and darker.

8. Michelson - Redchief. Deep, black loamy soils on dissected high elevation benchlands. Both have black surface soil and brown clay loam subsoil. The substratum of Michelson is white alkaline clay loam while that of the Redchief is acid red gravelly clay. Redchief areas are commonly gently sloping. Both gently sloping and sloping phases of Michelson are common.

9. [illegible] - Adel. Dark colored soils on hilly and steep broken uplands with shale and sandstone bedrock. [illegible] soils are shallow over bedrock whereas Adel soils occur in accumulation positions and are deep. They are of equal extent.

10. Michelson - Bishkum: Deep, black soils on nearly level benchtops, adjacent steep bench-edges, and long footslopes. Michelson soils account for about seventy-five percent of the area. Bishkum soils are deep gravelly soils with thin, dark-colored topsoil.

11. Timberg - [illegible]: Rolling and hilly clay loam soils derived from red shale bedrock. Timberg and [illegible] soils each occupy about forty percent of the area. The remaining twenty percent has very [illegible] soils over shale and soils with dense clay pans. [illegible] soils occur in convex slope positions and are twenty to forty feet deep over bedrock. [illegible] soils occupy concave slope positions and are over forty [illegible] to bedrock.

12. [illegible] - Cabba: Deep [illegible] loam benchland soils, separated by areas of shallow soils over shale bedrock or seeped saline waterways. The association is sixty percent [illegible] soils, twenty percent Cabba soils, and twenty percent seeped saline waterways. [illegible] soils are deep and loamy with moderately thick topsoil. Cabba soils are shallow, with thin, light-colored topsoil.

13. [illegible] - Hanson: Deep, dark-colored soils on rolling and hilly stony loam glacial till from limestone sources. Both occur in about equal proportions in complex patterns. Hanson soils are on stony ridges and slopes in [illegible] with Raynesford soils between. Raynesford soils have dark colored topsoil and nearly white subsoil. Hanson soils are lighter colored.

Soils of the Midgrass Prairie

14. Fairfield - Cabba: Deep, loamy soils of benchlands broken by areas of shallow soils over shale bedrock. Fairfield soils of the benchland remnants occur on about sixty percent of the area. They have dark colored topsoil and white alkaline subsoil. The Cabba soils occupy thirty percent of the area. They are light-colored and have soft shale bedrock within twenty inches.

15. Fairfield - Martinsdale: Deep, well-drained loamy soils on smooth, nearly level benchland areas. Fairfield and Martinsdale soils cover about eighty percent of this unit, the remaining twenty percent consists of steep bench edges, wet or saline swales, and areas of shale or sandstone bedrock. Fairfield and Martinsdale soils are similar in profile features, having loam or gravelly loam topsoil, brown clay loam subsoil, and white substrata than Fairfield.

16. Williams - Zahl: Deep, loamy soils on undulating, rolling, hilly, and steep glacial till deposits. Williams soils have dark-topsoil and the Zahl soils have thin light-colored topsoil. Williams soils occupy sixty to seventy percent of the area and Zahl about thirty percent.

17. Pendroy - Attewan: Nearly level and moderately sloping areas of clayey, loamy and sandy soils on glacial lake sediments. Penroy soils are friable clays with strong granular surface structure. Attewan soils are moderately deep, sandy or loamy over loose sands. Each accounts for about one third of the association. The remaining one third is a variety of deep loamy soils which are generally more friable than the Pendroy and which store more water than the Attewan.

18. Boswell - Tanna: Moderately deep, silty and clay loam soils on rolling and hilly siltstone and shale uplands. Boswell soils are silty and Tanna soils are clay loam. They are about equal in extent and together account for eighty percent of the area. The remaining area is shallow, light-colored loam and clay loam soils on knolls, ridges and steep slopes.

19. Attewan: Nearly level and sloping areas of sandy loam soils over loose sands at two to three feet. About twenty percent of the area is terrace escarpment, sandstone or shale bedrock, active sand dune or vegetated loose sand.

20. Scobey - Kevin: Deep, loamy soils on undulating, rolling, and hilly glacial till deposits. Scobey soils occupy half of the area, Kevin soils about forty percent, and other soils ten percent. The pattern is complex. Kevin soils occur on ridges and knolls. They are lighter colored and have thinner topsoil than the Scobey soils. Swales and closed basins are poorly drained and small lakes are common.

21. Cabba - Wayden: Shallow soils underlain by loamy or clayey shales on rolling, hilly, and steep uplands. Cabba soils are loamy and Wayden soils are clayey. They occur together in places but there are areas where one or the other is fairly continuous. Both soils have light-colored topsoil and are low in native fertility.

Soils of [illegible] Vegetation Types

22. Gallatin - Beaverton: Deep loamy soils and shallow gravelly soils on low bottomlands and adjoining stream terraces. Gallatin soils occur on about forty percent of the area. They are deep, loamy textured and have varying degrees of natural drainage. The Beaverton soils are shallow gravelly loams underlain by loose gravel. They occur on about forty percent of the area as a whole but are not common in some parts, especially along the South Fork of the Milk River. The remaining land is miscellaneous saline, wet and overflow areas.

23. Vanda. Dense clay soils on nearly level plains bordering intermittent streams and saline lakes. The soils are sticky and puddle when wet, and hard and crusty when dry.

24. Steep Broken Valley Sides. Areas where major streams are deeply entrenched in shale or sandstone bedrock. Typically about half the area lacks vegetation cover. The remainder varies from shallow loamy or clayey soils with sparse cover to pockets of deep soil with good plant growth.

The final test of the success of any irrigation project is the ability of the land to provide economic benefits; it follows, therefore, that land selected for irrigation should ensure that this objective can be achieved. The most important phase of land classification is the separation, according to suitability of the lands satisfactory for irrigation development, which are termed "irrigable" from inferior, non-irrigable lands. The term "irrigable land" as used in connection with land classification in the Water Resources Surveys is defined as lands suitable for irrigation by gravity or sprinkler methods. The land must have soil, topography and drainage features which will withstand a sustained irrigated agriculture.

Another important phase of the land classification process is the division of lands into classes on the basis of their relative degree of suitability for irrigation farming. Class 1 represents irrigable lands with a potentially high productive value; class 2 represents land of intermediate value; and class 3 includes lands of the lowest productive value that may be considered. Class 6 lands are of low productivity and are considered non-irrigable. Specifications for land classification as used by the Montana Water Resources Board are included in Appendix E of this report.

The intensity of the land classification surveys made by the Water Resources Board for potential irrigation development should be considered as general reconnaissance surveys, and any future irrigation project development should be based on a detailed study.

Detailed soil and land classification studies have been completed on only a very few of the potential projects in the Study Area. A land resources study for the Marias-Milk Project has been completed and will be published as an appendix to the project report. This appendix will include a detailed land classification study for the Milk River Valley, the Big Sandy area, and the Central Marias area.

The areas outlined as "irrigable" on the irrigation maps in Part X of this report show irrigable land classes 1, 2 and 3. The irrigable lands as shown have been published previously in the Water Resources Surveys for all counties in the Study Area with the exception of Pondera, Chouteau, Phillips and Valley. Irrigable areas (classes 1, 2 and 3) for these counties were obtained from work prints at the Montana Water Resources Board office. The presently irrigated lands are also shown on the irrigation maps within this report. Table III-1 summarizes the presently irrigated and potentially irrigable land within the Study Area.

A brief description of the amount, type and location of lands warranting further investigation for irrigation potential is given below for each county. The information presented is generally abstracted from the findings of reconnaissance surveys made by the Land Classification Section, Montana Water Resource Board.

TABLE III-1

Land Presently Irrigated or Potentially Irrigable

County	Presently Irrigated Land (Acres)	Potentially Irrigated Land (Acres)
Glacier	25,897	460,989
Pondera	124,618	337,458
Chouteau	13,011	572,672
Liberty	6,347	410,180
Toole	7,943	202,225
Hill	9,828	38,100
Blaine	69,985	208,500
Phillips	87,141	209,274
Valley	70,096	334,866
Total	414,866	2,774,264

Continental Glacial Soils:

The major event in the geologic history that influenced the soils of the Study Area was continental glaciation. The Keewatin ice sheet which developed in central Canada during the Late Wisconsin period of Glaciation spread over the greater part of southern Alberta and northern Montana, east of the main range of mountains. This major event influenced the soils of the northern plains, the sand, silt, clay, gravel, and boulders were picked up by the ice sheet which mixed them by crushing and then re-deposited the mixture know as glacial till. This mantle varies from less than one foot to over 100 feet in thickness. Although the glacier mixed materials it had carried for long distances with materials from underlying bedrock, in the main the largest percentage of till is of local origin; this means it strongly reflects the nature of the underlying bedrock.

Glacial material was deposited over most of the area of North Central Montana with the exclusion of the mountainous regions of the Bearpaws, Little Rockies, Sweetgrass Hills and Highwoods. The steep, rugged, and mountainous topography of the western, northern, and southern slopes of the Bearpaws does not have benches or gentle slopes extending over sufficiently large areas to merit irrigation development planning.

The soils of the rolling terrain are shallow to glacial till, and have a definite high lime zone which becomes shallower on the higher ridges. The only means of irrigation would be by sprinkler, and then with limitations. The limitations being a network of tile drainage and with proper application of water being applied to ensure leaching of salts. However, the amount of water applied would have to be sufficient to prevent salt accumulation in the root zone. The ordinary sprinkler heads would have to be enlarged to increase water application. Experiments performed in Canada showed salt accumulation increasing in areas where too little amount of water is applied by sprinkling. The amount of water application is not known at this time, however, future experiments could determine the proper practices to be followed.

The drainage of shallow glacial till soil is the most critical item of consideration in irrigation planning. The feasibility of irrigating an area depends upon adequate protective measures to keep the crop production at a high level for a sustained irrigated agriculture. The absence of constructed drainage will cause the water table to rise, and the salt from the soil and irrigation water to accumulate within the root zone. The construction of drainage, mainly tile drains, will prevent salinization of the root zone. Research experiments in Canada proved that shallow tile drains at 36'' depth, and spacing as close as 30 feet apart may be needed to adequately drain the shallow till soils.

The glaciated plains of the major portion of the six western counties of the Study Area comprise one of the better producing areas of dryland wheat and barley crops in the State. The quality of winter wheat is rated among the nation's highest. However, the annual precipitation is not consistent and prolonged periods of drought may curtail crop production for several years at a time. A study of potential benefits which might derive from irrigation development in the western portion of the area indicates that such a program would not only help to stabilize the agricultural economy but would also benefit the communities in the area.

The dryland cultivated areas of the western part of the Study Area cannot always be considered as irrigable land. The heavy clay loam and clay glacial tills may have a high exchangeable sodium content, or a bulk density in excess of 1.5 grams per centimeter which will not allow sufficient vertical or horizontal movement of subsurface water to prevent seepage and high salinity build up in irrigated lands. There are large acreages of heavy clay loam and clay tills underlying the surface soils at a depth of 24" to 48" which are beneficial for dryland cultivation and livestock grazing. However, irrigation of these areas is not recommended.

The glacial soils of the area west of the Milk River and Bearpaw Mountains and north of the Missouri River are, however, generally adaptable to irrigation development; a comparative area of large irrigated acreage is only a few miles north of the International Boundary, these are the irrigated farms near Lethbridge, Alberta. The irrigated economy of the Lethbridge area is very productive; the main crops are sugar beets, field and canning peas, alfalfa, potatoes, small grains, irrigated pasture, and sweet corn.

Glacier and Pondera Counties:

The mountain glaciers in Glacier and Pondera Counties originated in the highlands and moved down to lower elevations. The glacial till was deposited in recessional ridges and is variable in depth. The depth increases toward the mountains and in the valleys of some of the glacial streams. The till is very stony and contains the characteristic red, green, white, black, and mottled quartzite (a granular metamorphic rock composed essentially of quartz) and agrillites (a slightly metamorphased rock formed from sediments containing clay and silt) with some diorites and silica conglomerate.

The characteristic features of the glacial material as well as the manner in which the till was deposited has a direct influence on the soils, topography and drainage of the local area.

The St. Mary's Glacier was a huge ice sheet that exerted a pushing action causing a very rough, hummocky topography; an example is the area around Duck Lake. The glacial deposits consist of large cobbles and gravels with little intermixed soil material. There are scattered areas of loamy soils over the till with a sufficient depth to warrant potential irrigable class 3 land. However, the majority of the glaciated area is limited to rangeland for livestock grazing.

The Two Medicine or Blackfoot Glacier spread over a much larger area, the pre-glacial topography was a more gently rolling type. The glacial till material is generally shallow in depth over the bedrock. The erosion since glaciation has exposed the shale and sandstone parent material in places. The majority of the soils are shallow in depth and are used for rangeland. An exception is the area from northwest of Browning, east to the Two Medicine River in Range 6 West; measuring about 35 miles from east to west at an elevation of 3,900 to 4,500 feet. The soils here developed from a calcareous clay loam till. The soil profile consists of a thin dark colored soft granular "A1" horizon; a dark brown prismatic-blocky clay loam "B" horizon with distinct clay skins on ped surfaces; and a moderately developed horizon of lime accumulation in the upper part of the clay loam-till parent material. The limiting factors are the depth of soil over till; the amount of cobble and gravel in the upper soil profile; the rough or hummocky topography; and drainability of the soil. The majority of the soils that are irrigable are in Class 3. Included may be as much as 40 percent class 6 within a delineated area. The main crops under present irrigation are pasture and hayland.

There are small acreages of glacial outwash fans and low terraces that have soils and topography favorable for irrigation. The limiting characteristic is the depth to loose sand, gravel and cobble. Most of the areas are designated as irrigable class 3. The main potential land use is sprinkler-irrigated pasture and hayland.

Seville Bench is located in Glacier County west of Cut Bank. This large bench borders the valley of Cut Bank Creek on the south. It is about 14 miles long by 3 miles wide and slopes gently to the east. The bench is at elevations of 3,800 to 4,100 feet and lies 100 to 300 feet above the valley of Cut Bank Creek. It has a plain surface with low gravelly bars rising 1 to 2 feet above the ground level in the western part. The benchland terrace is underlain by as much as 40 feet of unconsolidated materials. The terrace deposits consist of a lower layer, of coarse gravel mixed with finer materials, and an upper layer, of sand, clay, silt and scattered pebbles and cobbles. This bench occupies an erosional surface younger than the high plateaus in front of the mountains, but was eroded to its present level before glaciation.

There are several of these plateaus and benches. The majority of irrigable class 1 and irrigable class 2 lands in Glacier County are located on these plateaus, benches and the slopes formed by erosion and recession of the benchlands.

The elevations of the plateaus and benches in Glacier and Pondera Counties vary from 3,800 to 6,200 feet which influences the climate. The climate influences the soil forming processes particularly the surface layers. The soil of high plateaus are Cryoborolls (Chernozems) soils. These soils may be in areas with less than a 90 day growing season. The summer temperatures are cool and evaporation is low. The surface is dark-colored for at least 10 inches, with a clay accumulation in the subsoil and a high lime zone below the clay subsoil.

The lower benches below 4,300 feet elevation have Argiborolls, Haploborolls and Calciborolls (Brown-Chestnut and Calcisol) soils. Their presence suggests a transitional climatic condition. These soils are characterized by moderately dark to dark colored surface layers less than 10 inches thick. The clay accumulation on the Argiborolls soils begins at about 3 inches, and extends to about 10. There is a lime zone at depths ranging from 7 to 15 inches.

The soils of the plateaus and benches are quite uniform, however, variable depth of dark colored soils above a high lime-zone occur in parts of the mapped areas. The lime layer is not considered as a limiting factor to irrigability except where the lime-zone occurs within the upper 12 inches of the surface. In this case the irrigable land class is lowered from class 1 to class 2 because of the difficulty of maintaining fertility and germination of some row crops.

The irrigable soils of Seville Bench and other benchlands are considered drainable, and the underlying gravelly deposits usually can be reached by drainage ditches. The construction of drainage ditches prior to and after irrigation development may be necessary for allowing maximum root zones for alfalfa and cultivated crops.

The benchlands and high plateaus may be considered as the best potential irrigable lands within Glacier and Pondera Counties. The main restricting factor in many of the areas is water delivery to the high benches which are several hundred feet higher than surrounding areas.

The valley lands along the Upper Milk River and its tributaries have several areas of Argiborolls soils forming on the terraces and bottomlands. The acreage of the irrigable soils is somewhat limited because of poor drainage and alkali; however, the value of the drained areas for hayland is quite high.

The shallow gravelly low terraces along the central portion of Cut Bank Creek, Birch Creek, Dupuyer Creek, and other present and ancient stream valleys are considered irrigable. The moisture-holding capacity of the soil is barely adequate to maintain growth of irrigated pasture or hayland. These are class 3 irrigable lands.

The lacustrine soils in Glacier and Pondera Counties vary in suitability for irrigation according to texture, permeability of the subsoil, and salt and alkali content. The salinity of the water in lakes varies according to the amount of salt present in the formation that the water passed through. There are several lake basins within the counties that have an unfavorable salinity level for crop production.

The lacustrine soils that have satisfactory texture, structure, permeability and salt content for irrigation are present in large bodies on very gently sloping lake plains, such as the areas north and south of Cut Bank and northeast of Valier. The majority of the lacustrine soils are in irrigable land class 3. This is because of permeability and poor workability.

Very careful irrigation water management is needed on lacustrine soils. Irrigation water should not be allowed to pond on the surface. Border dikes permit most efficient use of irrigation water if a sufficient head of water is available.

Livestock grazing is the principle agricultural use for much of the land in Glacier and Pondera Counties; however, dryland wheat and other small grains are grown extensively in the eastern part of the area. The majority of the irrigated land in Glacier County is located on Seville Bench west of the town of Cut Bank. There are other small tracts of irrigated land near the town of Browning and along the larger streams.

The expansion of irrigation can be accomplished in several areas, the largest is the remaining dryland cultivated and grassland area adjacent to the presently irrigated land on Seville Bench. The small acreages of irrigable land adjacent to the larger streams could be developed by individual land owners and the Blackfeet Indian Tribal Council. The remaining irrigable acreages of the benchlands and high plateaus will be very difficult to irrigate because of high elevation above the existing water supply. It may be possible to install pumps and lift water several hundred feet onto the benchlands and high plateaus; however, the high pumping costs may not be economically feasible at present.

The reconnaissance land classification of Glacier County shows a total of approximately 460,989 potential irrigable acres suitable for irrigation. There are 67,320 irrigable acres of class 1 land; 113,194 irrigable acres of class 2 land; and 280,475 irrigable acres of class 3 land. The class 3 irrigable acreages includes 53,139 acres which are

are limited to less than a 90-day growing season; except for this climatic limitation the acreage could be considered as class 1 or 2 lands. The reconnaissance land classification of Pondera County shows a total of approximately 337,458 potential irrigable acres suitable for irrigation. There are 15,957 irrigable acres of class 2 land, and 321,501 irrigable acres of class 3 land. The reconnaissance land classification does not attempt to separate the type of irrigation as to sprinkler or gravity. Considering the general nature of a reconnaissance study it is possible that detail studies will show either an increase or decrease in the irrigable areas by as much as 10 to 20 percent in some areas.

The climate of Glacier and Pondera Counties is considered a limiting factor for irrigated cultivated crops. The high benches and other areas above an elevation of approximately 4,300 feet have less than a 90-day growing season. Under irrigation these soils will produce hay and pasture but production of cultivated crops is marginal. The soils and topography of the areas may be favorable for irrigable land classes 1 and 2; however, because of the climatic limitation these irrigable lands are in class 3.

Drainage in agriculture is the process of removal of excess water from soil. Excess water discharged by flow over the soil surface is referred to as surface drainage. Water flow through the soil is termed internal or subsurface drainage. The terms "artificial drainage" and "natural drainage" indicate whether or not man has changed or influenced the drainage process. The evaluation of the soils and topography of the irrigated and potentially irrigable lands of Glacier and Pondera Counties show that artificial drainage is necessary in many areas.

The higher water table on the presently irrigated lands of Seville Bench and the adjoining area and large acreage of Pondera County show that artificial drainage is necessary to obtain sustained high crop yields. The construction of open ditch drains should correct much of the high water table difficulties of the presently irrigated lands.

It is anticipated that the expansion of irrigated agriculture in Glacier and Pondera Counties will be developed on a project basis. Whenever an area of irrigation project development is anticipated both a detailed land classification and drainage investigation should be completed prior to construction. The drainage survey will establish the cost of minimizing seepage and salinization of the soil. It should be remembered soil that has become seeped and strongly alkaline or saline to the point where crop production is curtailed, is a waste of arable cropland.

Liberty and Toole Counties:

Liberty and Toole Counties are located in the more shallow glacial drift-covered portions of the Great Plains. The greater part of the area is a high rolling plain, characterized by glaciated divides, sloping gently to the south. The Sweet Grass Hills rise several thousand feet above the plains in the north-central part and have a local influence on the drainage and climate. Erosion has not greatly changed the surface features of the glacial drift-covered area since the time of glaciation, except along some of the more deeply entrenched perennial streams and on the more shallow glacial drift-covered divides. With the exception of some of the buttes of the Sweet Grass Hills, the entire two counties are mantled earth material deposited by glacial ice.

There are 199,255 acres of potential irrigable lands in Toole County located on the glacial uplands and ancient lake beds of the plains. In Liberty County, there are an estimated 285,300 acres of potential irrigable land in rolling terrain covered with glacial till.

There are large areas of clay soils in Liberty and Toole Counties. The clay textured soils are generally not considered too satisfactory for irrigation. The limiting factors are poor drainage and high salinity. The exceptions are the heavy textured soils occurring on upland plains or on valley terraces with a high shrink-swell capacity which allows adequate drainage and aggregation for irrigation. Large areas of these soils occur on terraces and uplands above the Marias River and Tiber Reservoir.

The residual soils of Liberty County are divided into two separate origins; the mountainous non-glacial slopes of the Sweet Grass Hills, and the areas of sedimentary shales and sandstones in the northern part of the area and along the Marias River. The soils developed over sedimentary shales and sandstones are locally immature. These olive-brown heavy clays are without distinct soil horizons and usually have the platy structure of the shales below 1' to 3'. Beneficial use of the land is livestock grazing.

The mountainous non-glacial slopes of the Sweet Grass Hills have stony loams at elevations above 4,500 to 5,000 feet. Portions of these slopes have shallow, loamy, rocky soils developed over the parent material of sandstones and shales. The size and extent of the residual soils are not significant because of the intermixing of deeper soils of alluvial-colluvial origin. The beneficial use of the rocky slopes generally is for livestock grazing.

The Marias River Valley is the only source of large tracts of irrigable alluvial soils in this area. In Liberty County there are 1,180 acres and in Toole County there are 3,000 acres of potential irrigable

alluvial soils along the Marias River which flows in a southeasterly direction in a deeply entrenched valley 1/2 to 1 mile in width. Dark colored shales outcrop below the covering of glacial drift, and locally, colluvial wash from them extends down to the stream.

There are several areas of light to medium textured alluvial soils in the Marias Valley where irrigated agriculture is proving profitable. Additional pumping plants are needed to enhance the agricultural benefits of these tracts. The main limiting factor that should be considered in irrigation planning is the general topography of the area adjacent to the river; the meandering stream channel interferes with efficient irrigation systems. The areas of irrigable land are therefore small and generally can be considered only for limited river-pump irrigation by individual farmers.

The majority of small streams of Liberty and Toole Counties head in the Sweet Grass Hills and flow through narrow deeply entrenched valleys of the mountainous terrain, then broaden to an average width of 1/4 mile through the rolling uplands. The alluvial soils of these valleys have scabby land with slick spots, high alkaline content and seeped areas; the most beneficial use of the soil in these valleys is livestock grazing.

The dryland cultivated areas of Liberty and Toole Counties cannot always be considered as irrigable land. The heavy clay loam and clay glacial till may have a high exchangeable sodium content, or a bulk density in excess of 1.5 grams per centimeter which will not allow sufficient vertical or horizontal movement of subsurface water to prevent seepage and high salinity build up in irrigated lands. There are large acreages of heavy clay loam and clay tills underlying the surface soils at a depth of 24" to 48" which are beneficial for dryland cultivation and livestock grazing. However, irrigation of these areas is not recommended.

The 1,965 square miles in Toole County and 1,459 square miles in Liberty County that are basically utilized for dryland farming and livestock grazing which is the principle adaptable agriculture for the "Triangle" area of northern Montana. Wheat is the basic dryland crop and should remain so for some time. Irrigation would be very beneficial to the economy, however, the limited water supply hinders expansion. The ultimate development of any large acreage of irrigation would depend on importing water from another area. The reconnaissance studies of the land classification survey show approximately 202,225 acres in Toole County and 410,180 acres in Liberty County being suitable for irrigation planning; a further breakdown of the type of irrigation, either sprinkler or gravity, was not attempted by this survey. Considering the generalities of a reconnaissance study, it is probable that detail studies would decrease this irrigable acreage as much as 40 percent in some instances. It should be noted that any irrigation development would warrant a detail study of the soil, topography

and drainage for the purpose of evaluating the project area to withstand a sustained irrigated agriculture.

Hill and Chouteau Counties:

The reconnaissance land classification of Hill and Chouteau Counties has not been completed by soil scientists of the Water Resources Board, therefore, the estimated acreages of potential irrigable land shown on the irrigation maps for these counties are subject to change.

Chouteau County, which has had a general reconnaissance land classification for the greater part of the county, has approximately 572,670 acres of land worthy of consideration for irrigation planning.

Western Hill County has at least 24,600 acres of land worthy of consideration for irrigation. Soils and drainage surveys of the Bureau of Reclamation in the Marias-Milk project area show that the depth and permeability of the soil over till are adequate to allow installation of drains at a reasonable cost. Diversified irrigated farming of climatically adapted crops, such as sugar beets, small grains, alfalfa, and corn silage could be grown in this area. New technology in irrigation practices, and the need for greater crop production may warrant future consideration of irrigation planning on larger areas of the glaciated uplands in the western section of Hill County.

The glaciated plains, situated in the area of Beaver, Big Sandy, and Bullhook Creeks, contain 1,000 acres for potential irrigation planning. Drainage costs, however, would be high due to the shallow soil depth over a compact glacial till. Small acreages of this area presently are being irrigated from a storage reservoir and the main stream of Beaver Creek. The existing water supply is inadequate and the extent of seepage has not been determined at this time.

The soils in the northeastern section of Hill County were developed by glacial movement which deposited the shale-like material from the Bearpaw formation. These soils have a shallow solum with high alkaline salt content, and the desolate appearance of "slick spots", "scab-areas", and "blowouts". The dryland cultivated areas are limited to the better soils, but even these may be marginal. The principal land use in the northeast section of the county is the production of native grasses for livestock grazing.

The northern section of Hill County has numerous small glacial lakes which are supplemented by snowmelt water. The largest of these glacial lakes is Wild Horse Lake which intermittently fills with supplemental water; presently there are small tracts of irrigated land in the

northwestern portion of the lake bottom. The lacustrine soil deposits of the lake bottom are slowly permeable clays which are not considered satisfactory for irrigation. The land bordering the lake is rolling and undulating; the soil in the southwestern portion is light to very light textured. There are scattered areas of the light textured soils which may have potential for sprinkler-type irrigation, but a limiting factor would be a presently inadequate water supply. Exploration of underground water sources could determine the location, quantity, and quality of water available for pumping. A detailed land classification also would be necessary to locate the lands which may lend themselves to irrigation planning.

When the first continental ice sheets advanced southward, the area west of the Bearpaw Mountains and southwest of the Milk River had considerably greater topographic relief than at present. During the pre-glacial period the Missouri River flowed northeastward along the west base of the Bearpaws. Geologic data indicates the pre-glacial valley of the Missouri River is so completely filled with glacial deposits that there is little surface indication of the valley's presence. The alluvium of Big Sandy Creek and its tributaries has completely covered the glacial deposits except for a few glacial gravel terraces and small glacial lake areas. There are approximately 17,000 potential irrigable acres of alluvial deposited soils within the Big Sandy Creek Valley. The soil textures are loam to clay loam surface with coarser textured materials at lower levels. The alkalinity and salinity measurements are within the tolerance for growth of climatically adapted irrigated crops of sugar beets, small grains, alfalfa, corn and irrigated pasture grasses.

Only limited future irrigation development of the Milk River Valley from Fresno Dam to the Blaine County line seems to be practicable. There are 1,500 acres of potential irrigable land located in several small tracts from Fresno Dam to the Blaine County line; the soils are light to medium surface texture with coarser texture subsoils.

There are a number of small creeks which have headwaters in the Bearpaw Mountains. Most of these creeks flow north through the mountainous terrain, and terminate in the Milk River near Havre. Eagle Creek, Birch Creek and other small tributaries in Chouteau County drain to the southwest into the Missouri River. The narrow

valley of Beaver Creek has small tracts of irrigated land that are producing satisfactory yields of hay and alfalfa. The potential new land for irrigation is limited by the small acreages in the creek valleys and the small supply of available water.

The majority of the glacial plains west of the Milk River are drained by Sage Creek in Hill County. The narrow valley is undulating and the topography is divided into small tracts by the meandering creek channel and the small intermittent tributaries. The soils are formed from the local parent material which is high in alkalinity. The small acreage and the high alkaline soils do not warrant any extensive irrigation planning.

The northeastern part of Hill County is drained by small creeks which meander through the Bearpaw shale formation. The alluvial soils formed here are high in salinity, alkalinity, and clay content. The non-irrigable soils, limited water supply, and water quality have restricted the land use of the small creek valleys to dryland grazing.

The southwestern portion of Chouteau County is drained by the Teton River; the southeastern, eastern, and northeastern portions of the county are drained by the Missouri River; and the northwestern portion is drained by the Marias River. There are small acreages of alluvial land occurring along all streams and these may be flooded periodically. The only development that has occurred in these soils is the darkening of the surface by the accumulation of organic matter. The material below the surface is essentially the same as it was at the time of deposition.

The portions of Chouteau County that are east and southeast of the Missouri River generally do not have extensively large acreages of potential irrigable land because of the shallowness of glacial till which overlies shale material. The irrigation of these soils would cause large areas of seepage and alkali soils.

Blaine, Phillips and Valley Counties

The major event in the geologic history that influenced the soils of Blaine, Phillips and Valley Counties was continental glaciation. Sand, silt, clay, gravel, and boulders were picked up by the ice sheet which mixed them by crushing and then re-deposited the mixture known as glacial till, the nature of which is determined by the mixture in the path of the ice sheet. During the retreat of the ice, the running water segregated the material according to particle size. The coarse materials, sand, and gravels, usually settled out near the margins of the ice; the fine materials, silt and clay, settled out further from the ice margins and were often deposited in bodies of still water such as ponds and lakes. Material sorted and deposited by the melt is called glacial outwash.

The combination of the topography and undesirable till material have formed large areas of either or both soil and topography which are not desirable for irrigation planning. The majority of Blaine, Phillips and Valley Counties is range-land which grows grasses that are very satisfactory for cattle and sheep grazing. There are also large acreages which have a medium textured surface soil with a great enough soil depth over the till substratum to produce dryland wheat.

There are large areas of glacial uplands which are rolling terrain and relatively shallow to glacial till which are generally not adaptable to future irrigation development. The depth to till usually is above 48 inches. There are however, approximately 315,000 acres of potential irrigable land within the glacial uplands of Blaine, Phillips and Valley Counties. The irrigable soil overlying the till is generally of clay loam surface texture with a loam to clay loam subsoil. The salinity is within the tolerance of most plants, leaching the soluble salts from the subsoil is possible within the irrigable land areas. The limitations being a network of tile drains to ensure proper drainage. The method of irrigation would generally be by sprinkler, with large enough sprinkler heads to allow adequate water application for leaching.

There are approximately 15,000 acres of potential irrigable land in Valley County east of Vandalia between the Milk River and Fort Peck Reservoir. The topography of the glaciated uplands is rolling and of a gently to moderately sloping gradient. The gentle slopes and rolling topography of the ridges will permit sprinkler irrigation; with adequate drop structures and irrigation ditches, gravity irrigation; would be possible. The soils are of a clay loam surface texture with a clay loam to silty clay loam subsoil. The salinity is within tolerance of most plants; leaching the soluble salts from the clay loam subsoil is possible within the irrigable land areas.

The exception to the general glaciated pattern north of the Milk River in Blaine and Phillips Counties is the large upland area known

as the "Big Flat". The overall size of this area is estimated at 141,000 acres of which 132,000 acres lie in Blaine County and 9,000 acres are in Phillips County. The soils, loam textured, are well developed over a friable loam ranging to a clay-loam glacial till underlain by gravel and sand which indicates that the glacial deposits are situated over high terrace gravels. The general terrain is split into two large main and several smaller broad glacial melt-water valleys. The soils of the broad valleys are of either sandy or loamy materials over loose sand gravels occurring at an estimated 20" to 30" depth.

The "Big Flat" area warrants consideration for irrigation in those sections limited to the gently sloping, smooth terrain and soils which have adequate water holding capacity. The principal limiting factor is the water supply although underground water bearing gravels are within reach of turbine type irrigation pumps. The quantity of water known to be available is sufficient to irrigate a sizeable area. However, this source of water would have to be subjected to further study as to quality, quantity and source before consideration should be given to any large scale irrigation developments.

The eastern portion of Valley County is covered by high gravelly plateaus; an area of 650 square miles was laid down by ancient streams before the time of glaciation. There are approximately 227,000 acres of potential irrigable land on these high plateaus. An example is the large plateau around Opheim and Richland which slopes to the south and grades into the glaciated uplands at about an elevation of 2,800 feet. The stream deposits are known as Flaxville gravel plateaus; these were probably thinly glaciated to the extent that the higher elevations were above the glaciers. The glacial drift deposits have not modified the character of the soils to any great extent, the exception being near the plateau borders. The plateaus are separated by wide, deep stream depressions of which the main drainages are West Fork of the Poplar River, Roanwood Creek, Cottonwood Creek, Middle Fork Porcupine Creek, Little Porcupine Creek, and the West and Middle Fork of Wolf Creek. The tops of the larger benches are 200 to 500 feet above the glaciated plains. Their surfaces are level and gently rolling, but their borders are in places deeply indented by streams causing the formation of local hills, ridges and buttes.

The general topography of the large area near Opheim is a gently to very gently rolling surface which varies from a 2% to 5% slope. There are large tracts of land scattered throughout the general area that can be irrigated by gravity; however, the majority of the area would be considered for sprinkler type irrigation.

The southeastern portion of Valley County and the southern portions of Blaine and Phillips Counties and other badland areas along the breaks of streams have shallow undeveloped soils overlying the geological formations of the breaks. The large area of Bearpaw and claggett shale badlands border the Missouri River in the southeastern portion of the County. The shale beds have weathered into dome-shaped hills and ridges, between which are either cut-bank coulees or gently sloping depressions having the character of bad-land basins. The beneficial use of the bad land areas is only for livestock grazing.

Alluvial soils occur along all streams of the area, the largest stream being the Missouri River; however, the second largest stream, the Milk River, is of more agricultural importance. The soils distinguishing characteristics are influenced by their parent material but also to some extent to the degree of development under the agency of the soil forming process. The material below the surface is essentially the same as it was at the time of deposition. Most of the alluvial soils of Valley County are found in the Milk River and Missouri River Valleys, with some being along every stream or drainage throughout the county.

The alluvial soils can be divided into two characteristic soil forming processes; first, the most recent alluvial deposits which occur along present streams and drainages; second, the alluvial deposits from the pre-glacial rivers, the Missouri and Musselshell, with other smaller deposits from many pre-glacial creeks and drainages. The division of the two soil forming processes cannot be easily distinguished because most of the present streams are flowing in the pre-glacial stream valleys.

There are several large acreages of light to medium textured alluvial soils, irrigated agriculture is proving profitable on these soils. Additional drainage facilities are needed in some of the areas to enhance the accrual of agricultural benefits. There are 19,150 acres immediately adjacent to the Milk River that are suitable for irrigation development, but land leveling and clearing of deciduous trees is a prerequisite. The main interfering factor that should be considered in irrigation planning is the general topography of the area adjacent to the river. Many oxbows and sloughs are present; also, the meandering channel of the river interferes with the land forms. The areas of potential irrigable land are therefore small and generally can be considered only for river pump irrigation by individual farmers. The development of canals for service to large areas of alluvial soils is not generally possible.

The Bearpaw and Little Rocky Mountains are located in the southwestern and southeastern portions of the area. The glacial plains flank these mountains. There are streams heading in the mountains and flowing in the northeast direction to their termination into the Milk River.

The main streams which have areas of land being irrigated and potential irrigable lands which can be developed are Peoples, Little Peoples Creek and Clear Creek. The alluvial soils in these narrow valleys are very dark colored loam to clay loams which are relatively free of salinity and comprise an estimated 11,000 acres which could be considered for irrigation planning if adquate water supplies were available.

There are numerous small creeks on the north side of the Milk River which have narrow alluvial valleys of saline and alkaline soils. The parent material which these streams meander through is mainly Bearpaw shales which add an undesirable alluvium wash of heavy alkaline material to stream valleys. The two main forks of the Milk River are Lodge and Battle Creeks where there are situated small tracts of presently irrigated land, and an additional 11,000 acres that could be considered for future irrigation planning. The soil is relatively free of salinity and consists of a very dark colored loam to clay loam texture. These streams head in Canada and for some unknown reason the alluvium deposits are of a more desirable texture and salinity for irrigation planning than most creeks north of the Milk River.

The extreme fine textured soils which tend to predominate in the Milk River Valley can be related to the parent materials. The local names of the heavier textured soils are the Bowdoin clay, Harlem clay, and Orman clay loam series. These soils are formed from various outwash materials of the Bearpaw shale formations that outcrop in the breaks bordering the valley. The clay soils have similar characteristics, and the irrigation management should be uniform. Approximately one-fourth of the irrigated land in the Milk River Valley is on these clay soils. The percentage of heavy textured soils being irrigated in Phillips County will be considerably higher due to the vast areas of clay soils west of Malta, near Hinsdale and Saco, Montana. The clays are somewhat similar in physical characteristics, but a number of variations exist in depth and amount of stratifications of lighter textured materials. Leaching in agriculture is the process of dissolving and transporting soluble salts by downward movement of water through the soil. Because salts move with water, salinity depends directly on water management, that is irrigation, leaching and drainage. These three aspects of water management should be considered collectively in the overall plan for an irrigated area if maximum efficiency is to be obtained. If we apply this concept to the irrigation of heavy soils in the Milk River and other streams, the first obstacle is drainage. The slowly permeable clays that extend below 48" and have very few stratifications of lighter soil allow very little vertical movement of water and eventually the salt content will be above the toxic limit for the crops grown. There are many areas in the stream valleys where only blue joint hay (western wheat grass) will grow, in many cases crop productivity is nil.

The vast areas of Blaine, Phillips and Valley Counties are basically utilized by livestock grazing which is the main adaptable agriculture for this region. Irrigation is a very beneficial means of stabilizing this economy; however, future expansion is limited to the smaller acreage of favorable soil for an expanded irrigated agriculture. Considering the generalities of a reconnaissance study, it is probable that detailed studies would decrease the potential irrigable 752,640 acres. This is due to the fact that soils are not very adaptable to irrigation and a detailed land classification would eliminate some of the shallow till areas included in a general reconnaissance survey.

D. LIMITING FACTORS

The major limiting factor to irrigation development throughout the area is drainability. The glacial soils which cover an extensive area of North Central Montana often have heavy-textured and highly saline till substratum at shallow depth which makes drainage difficult and expensive. In many areas there is sufficient depth of medium or light textured soil over a till substratum for sustained irrigation, but drainage should be given careful consideration during project planning.

The extremely fine textured soils such as Bowdoin clay which tend to predominate in the Milk River Valley can be related to the parent materials. These soils are formed from various outwash materials of the Bearpaw shale formations that outcrop in the breaks bordering the valley. As much as one-fourth of the irrigated land in the Milk River Valley is on clay soils. The use of these soils for irrigation depends upon the depth to the light textured substratum; in general the areas with less than 36-inches of clay over the light textured material can be utilized by growing western wheat grass (blue joint) and some alfalfa hay crops. The deeper clay soils are a risk for even blue joint hay production. The surface generally becomes saline and alkaline-saline in nature, retarding plant growth and eventually causing a non-productive area.

It is interesting to note that there are numerous irrigated areas in the Milk River Valley where the depth of clay is 48 inches or more and there is no light textured substratum. By the standards used by the Montana Water Resources Board today, these lands would be class 6 - unsuitable for irrigation. Lands of this type are not being considered for any future irrigation development. The low yields of blue joint hay will continue on deep heavy clay soils only with proper water management of either one spring irrigation or large heads of water for short durations of time, otherwise non-productive areas will eventually result due to high saline and alkaline soil.

Related to the drainage and abundance of shale parent materials is the alkaline-saline problem which exists over much of the area. Careful consideration should be given to the type and extent of drainage required for any future irrigation project. Generally, the lands, classes 1, 2 and 3 irrigable based on reconnaissance surveys as shown in the irrigation maps of this report can withstand sustained irrigation if adequate drainage is provided. Detailed soil and land classification surveys will be required for each project to accurately locate the areas best suited to irrigation development. The detail studies of an irrigation project should include a drainage survey to determine the costs of minimizing seepage and salinization of the soil. It should be remembered that soil which has become seeped and high alkalinity and salinity results to the point where crop production is curtailed is a waste of irrigated or dryland cultivated land.

A restricting factor over much of the Study Area is inadequate water supply from either ground water or surface supply sources. Many of the streams are ephemeral and do not provide a reliable source of supply. Ground water development has generally been limited by poor quality and low yields. There are some areas deserving study for ground water development, but these are generally in the alluvial river valleys which have surface water available. Large areas in Toole and Liberty counties and areas remote from the perennial streams are limited by water availability. These areas will continue to be dryland areas.

A limiting factor in some areas is climate. The growing season on the high plateaus and benches in Glacier County are less than 90 days. In these areas, production of cultivated crops is marginal, but under irrigation the soils will produce hay and pasture.

Topography limits irrigation development in several areas. Surface slope in some areas is too steep for gravity irrigation; however, the majority of the area would be considered for sprinkler type irrigation. There are some areas immediately adjacent to the Milk River that are suitable for irrigation but land leveling and clearing of deciduous trees is a prerequisite. The main interfering factor that should be considered in irrigation planning along some of the Milk River Valley, such as in Valley County, is the general topography of the area adjacent to the river. Many oxbows and sloughs are present; also, the meandering channel of the river interferes with the land forms. The areas of irrigable land are therefore small and generally can be considered only for pump irrigation from the river by individual farmers.

E. LAND USE

Existing land use in the Study Area can be broadly classified as rangeland, cropland, forest and other. The majority of the land in the three eastern counties of Blaine, Phillips and Valley and in the Western-most county of Glacier is uncultivated rangeland. Pondera, Liberty and Hill counties have more land in crops than in rangeland, and Chouteau and Toole counties have about equal amounts of rangeland and cropland.

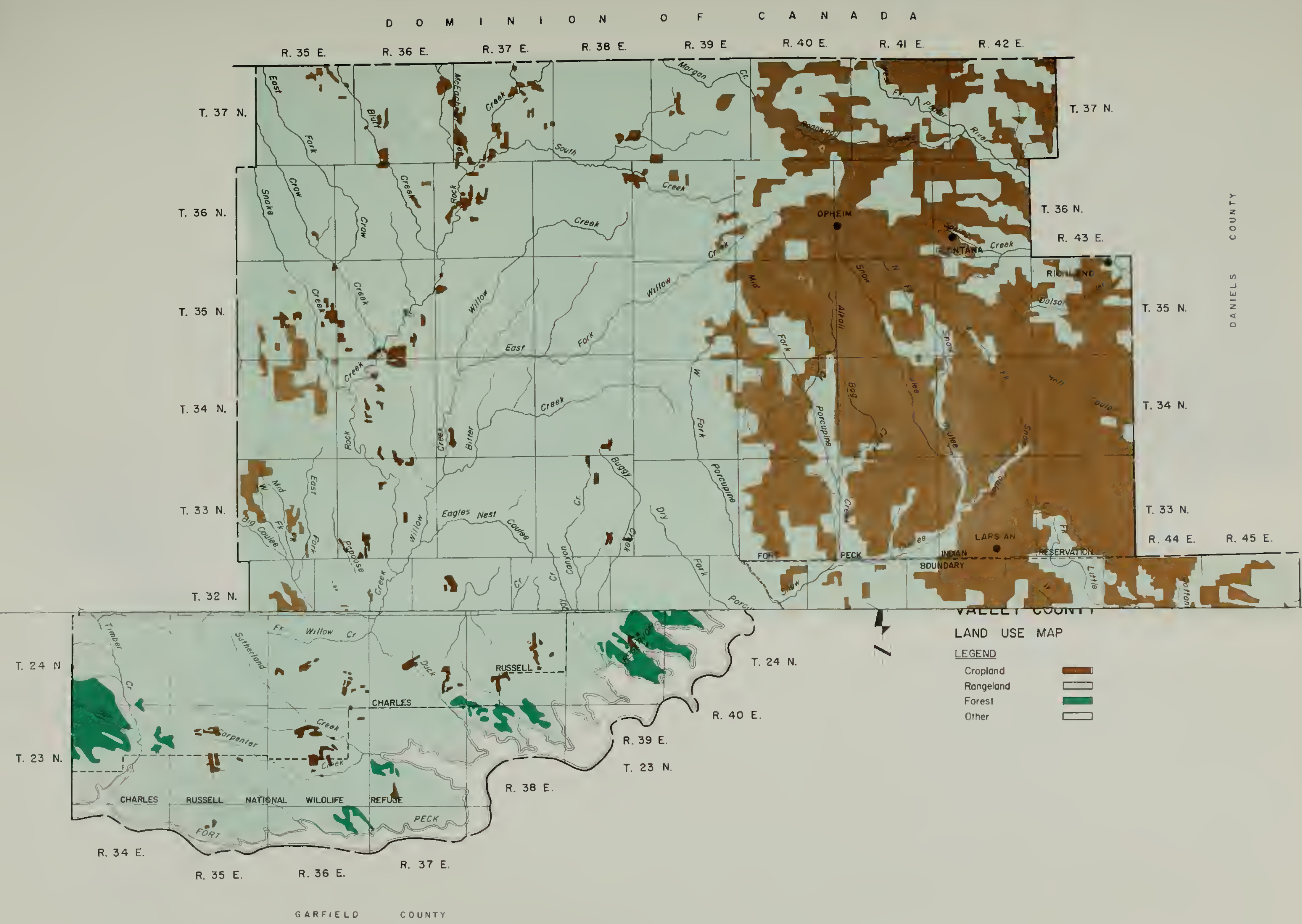
The land use maps in this report were based on information supplied by the Soil Conservation Service offices in the nine counties.[1] All presently irrigated land, including irrigated pasture, was classified as cropland when it could be distinguished from non-irrigated rangeland on the aerial photographs. The vast majority of the cropland is dryland farmed with the principle crops being wheat, barley, alfalfa and hay. Land placed in the "other" classification includes badlands, wastelands, lakes and marshes. The forest classification includes all wooded areas. All land which did not fall under one of the other categories was shown as rangeland. Estimated existing land use acreages are summarized in Table III-2.

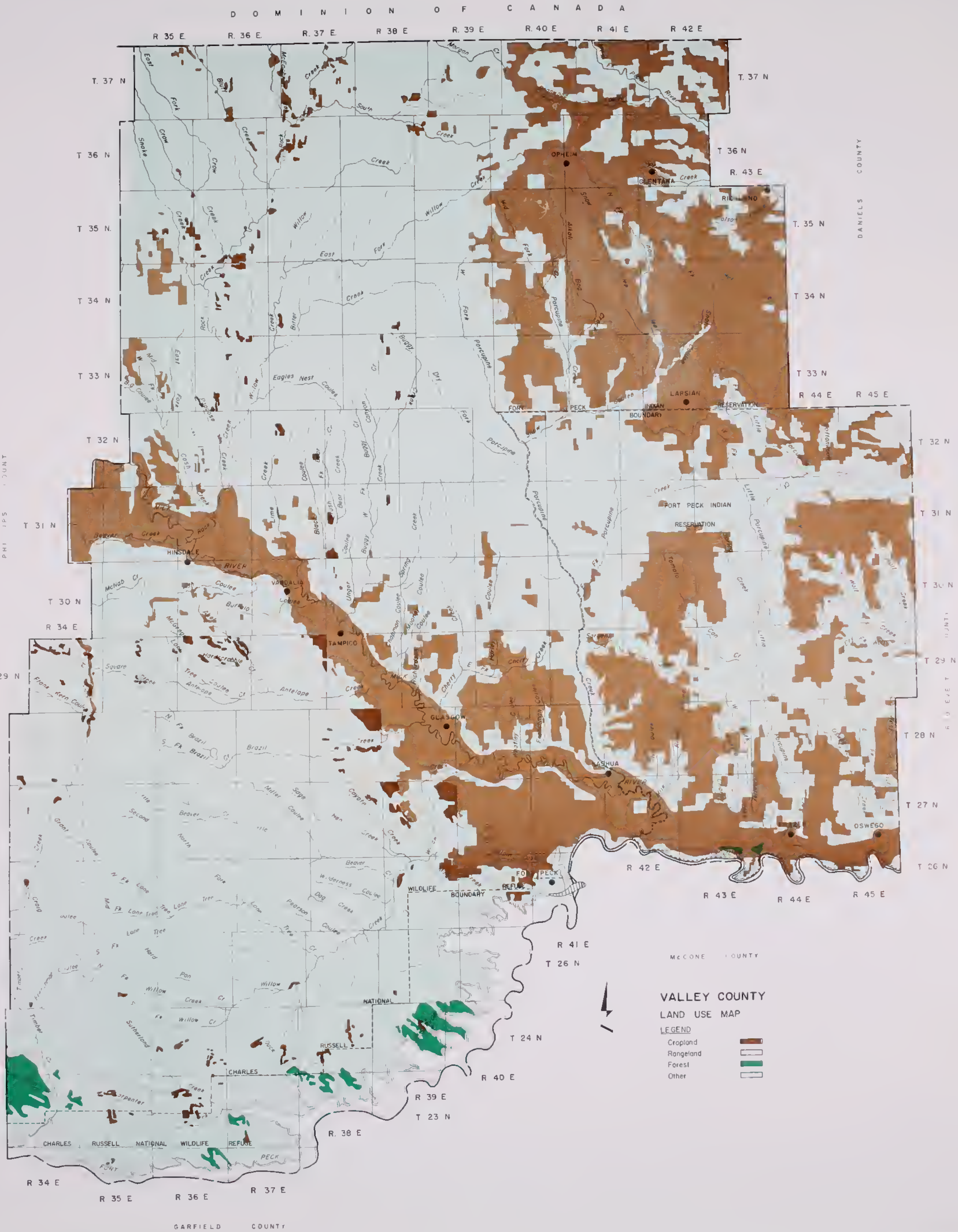
Numbers refer to footnotes located at the end of this chapter.

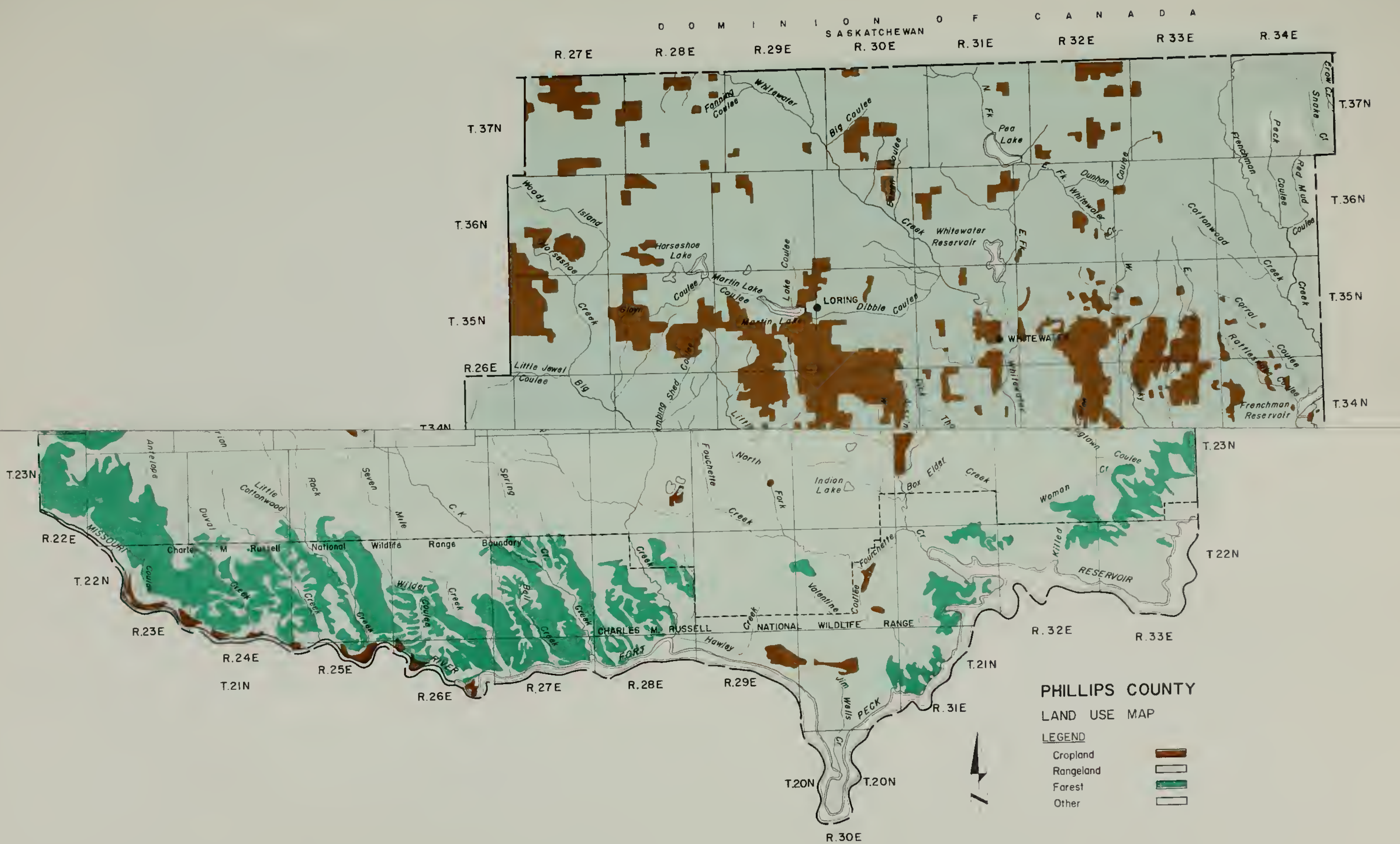
TABLE III-2

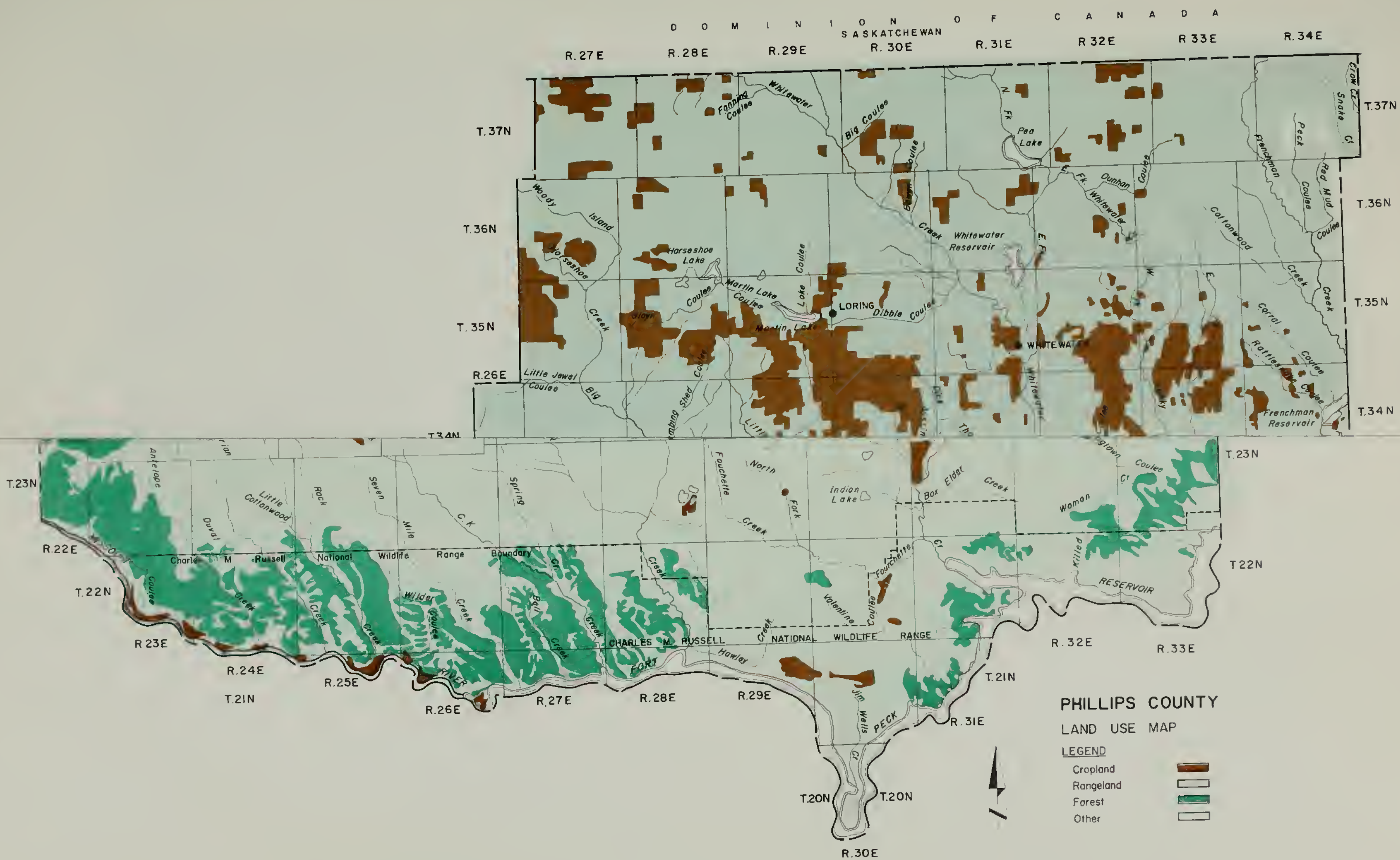
ESTIMATED EXISTING LAND USE ACREAGES

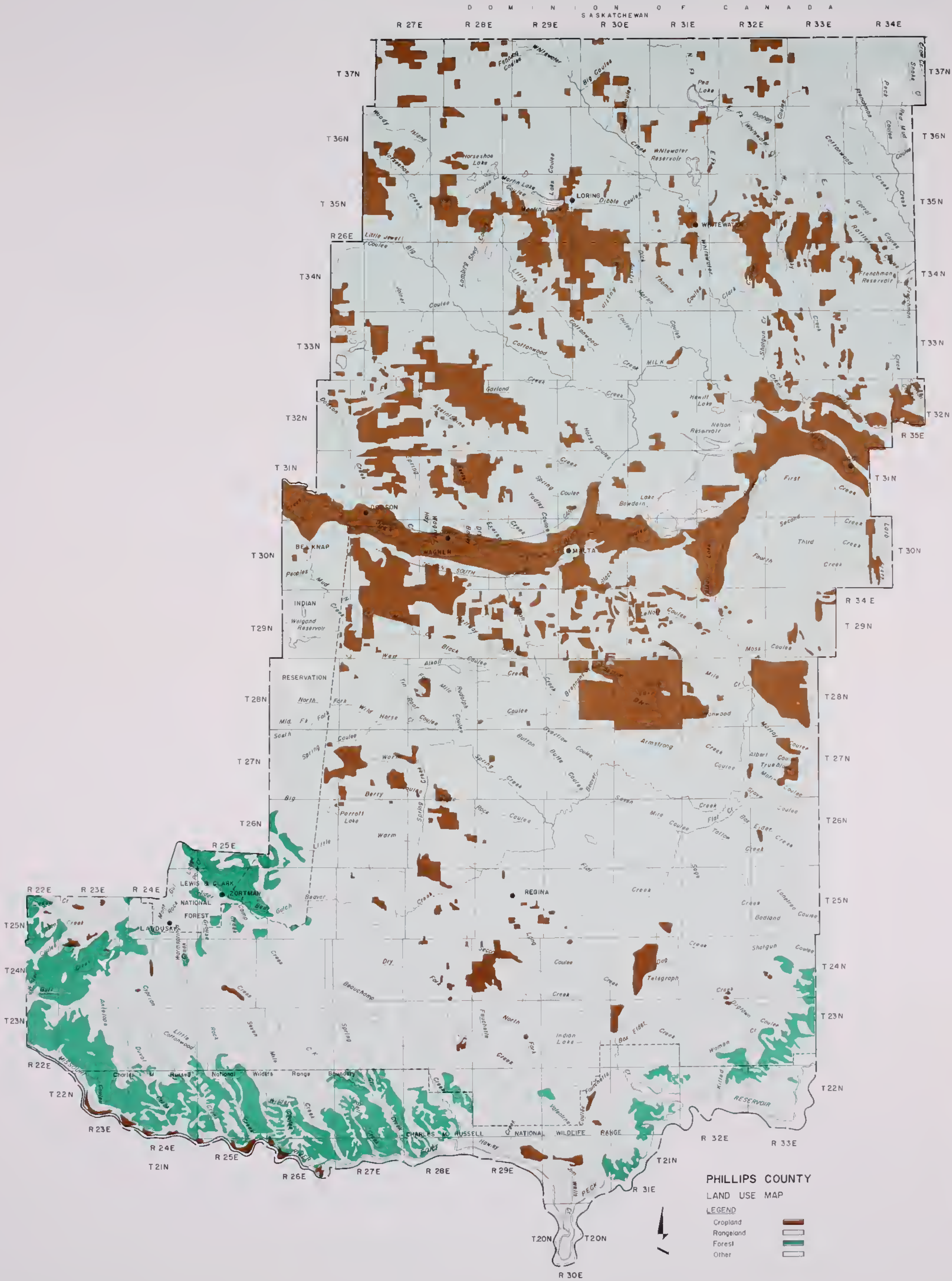
County	Cropland	Rangeland	Forest	Other	Total
Blaine	341,688	2,307,229	60,000	21,963	2,730,880
Chouteau	1,063,100	1,395,000	39,000	11,700	2,508,800
Glacier	341,000	1,027,600	540,000	38,663	1,947,263
Hill	1,005,665	758,905	8,000	100,070	1,872,640
Liberty	549,491	334,488	9,518	39,623	933,120
Phillips	303,000	3,030,200	6,000	5,800	3,345,000
Pondera	552,800	330,879	105,000	62,841	1,051,520
Toole	603,500	563,007	9,000	72,493	1,248,000
Valley	715,000	2,287,811	16,819	20,370	3,040,000
TOTAL	5,475,244	12,035,119	793,337	373,523	18,677,223


DOMINION OF CANADA
DANIELS COUNTY
GARFIELD COUNTY
VALLEY COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other
OPHEIM
RICHLAND
LARSLAN
FORT PECK INDIAN RESERVATION BOUNDARY
CHARLES RUSSELL NATIONAL WILDLIFE REFUGE
R. 34 E.
R. 35 E.
R. 36 E.
R. 37 E.
R. 38 E.
R. 39 E.
R. 40 E.
R. 41 E.
R. 42 E.
R. 43 E.
R. 44 E.
R. 45 E.
T. 23 N.
T. 24 N.
T. 32 N.
T. 33 N.
T. 34 N.
T. 35 N.
T. 36 N.
T. 37 N.


VALLEY COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other
DOMINION OF CANADA
DANIELS COUNTY
McCONE COUNTY
GARFIELD COUNTY
R 35 E
R. 36 E
R. 37 E
R 38 E
R. 39 E
R. 40 E
R 41 E
R 42 E
R. 43 E
R 44 E
R 45 E
R 34 E
T. 37 N
T 36 N
T 35 N
T 34 N
T 33 N
T 32 N
T 31 N
T 30 N
T 29 N
T 28 N
T 27 N
T 26 N
T 25 N
T 24 N
T 23 N
OPHEIM
GLENTANA
RICHLAND
LARSLAN
HINSDALE
VANDALIA
TAMPICO
GLASGOW
NASHUA
OSWEGO
FORT PECK
FORT PECK INDIAN RESERVATION
FORT PECK INDIAN RESERVATION BOUNDARY
WILDLIFE BOUNDARY
CHARLES RUSSELL NATIONAL WILDLIFE REFUGE
RIVER
Porcupine
Buggy
Willow
Beaver
Brazil
Antelope
Cherry
Rock
Creek
Coulee


PHILLIPS COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other
DOMINION OF CANADA
SASKATCHEWAN
R. 27 E
R. 28 E
R. 29 E
R. 30 E
R. 31 E
R 32 E
R 33 E
R. 34 E
T. 37N
T. 36N
T. 35N
T. 34N
T. 23N
T. 22N
T. 21N
T. 20N
R. 26E
R. 22E
R. 23E
R. 24E
R. 25E
R. 32E
R. 33E
LORING
WHITEWATER
Whitewater Reservoir
Frenchman Reservoir
Pea Lake
Horseshoe Lake
Martin Lake
Indian Lake
CHARLES M. RUSSELL NATIONAL WILDLIFE RANGE
Charles M Russell National Wildlife Range Boundary
MISSOURI RIVER
FORT PECK RESERVOIR


PHILLIPS COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other
DOMINION OF CANADA
SASKATCHEWAN
R.27E
R.28E
R.29E
R.30E
R.31E
R32E
R33E
R.34E
T.37N
T.36N
T.35N
T.34N
T.23N
T.22N
T.21N
T.20N
R.26E
R.22E
R23E
R.24E
R.25E
LORING
CHARLES M. RUSSELL NATIONAL WILDLIFE RANGE
Charles M Russell National Wildlife Range Boundary
FORT PECK RESERVOIR
Whitewater Reservoir
Frenchman Reservoir
Martin Lake
Horseshoe Lake
Pea Lake
Indian Lake
Woody Island Creek
Little Jewel Coulee
Big Coulee
Fanning Coulee
Dibble Coulee
Box Elder Creek
Woman Coulee
Killed
Antelope
Duval
Little Cottonwood
Rock
Seven Mile
Spring
C.K
Fouchette Creek
North Fork
Valentine Creek
Jim Wells Cr
Wilder Coulee
Bell Creek
Hawley
Cottonwood Creek
Corral Coulee
Rattlesnake Coulee
Frenchman
Peck Coulee
Red Mud Coulee
Snake Cr
Crow Cr



DOMINION OF CANADA
SASKATCHEWAN
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R 25E
R 24E
R 23E
R 22E
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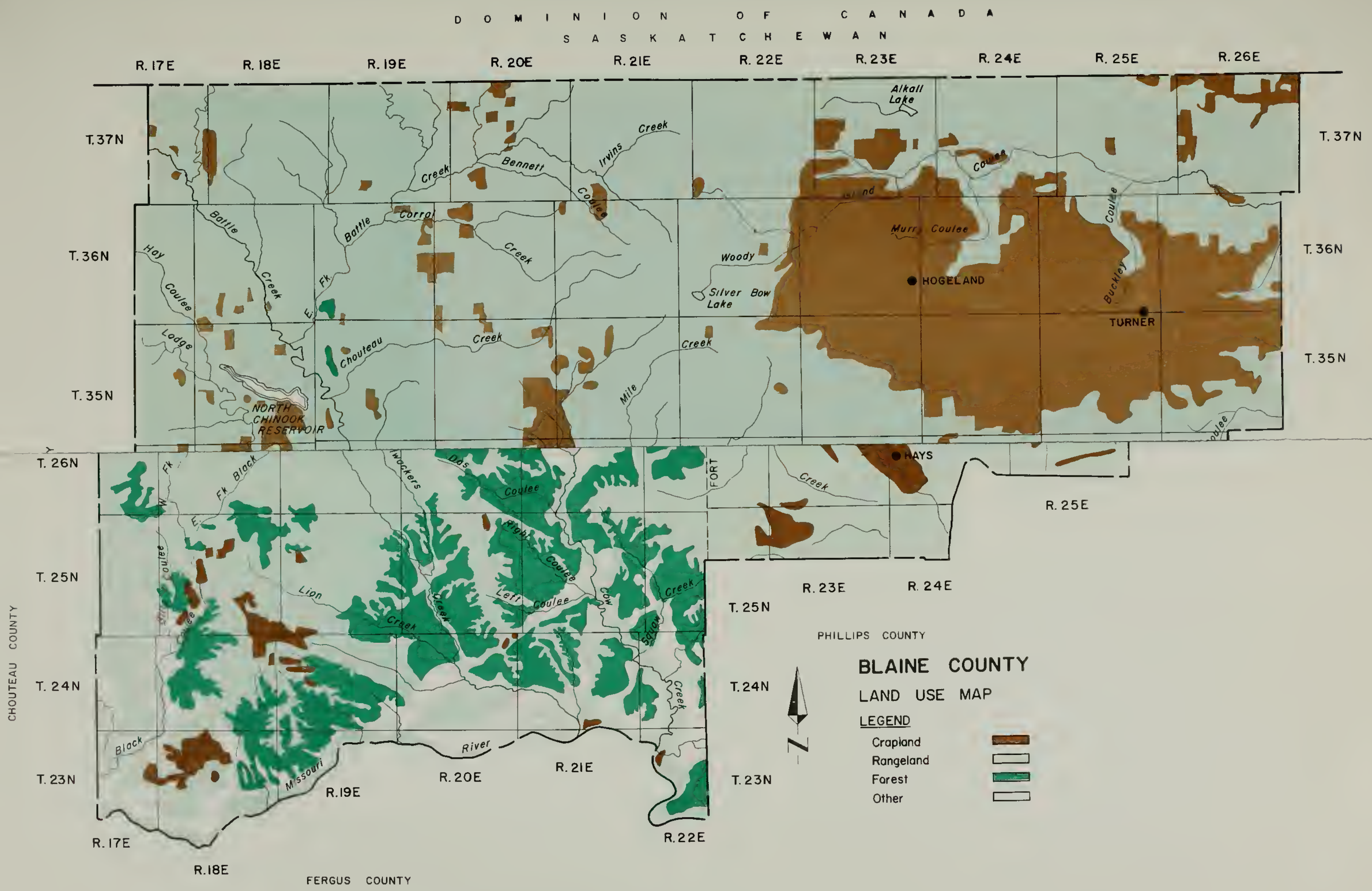
T 20N
LORING
WHITEWATER
Whitewater Reservoir
Frenchman Reservoir
Nelson Reservoir
DODSON
WAGNER
MALTA
BELKNAP
INDIAN
RESERVATION
Weigand Reservoir
LEWIS & CLARK
NATIONAL
FOREST
ZORTMAN
LANDUSKY
REGINA
MILK
Garland
Bowdoin
Indian Lake
CHARLES M. RUSSELL NATIONAL WILDLIFE RANGE
Charles M. Russell National Wildlife Range Boundary
MISSOURI
RIVER
RESERVOIR
PECK
R 30E
PHILLIPS COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other



DOMINION OF CANADA
SASKATCHEWAN
BLAINE COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other
PHILLIPS COUNTY
FERGUS COUNTY
CHOUTEAU COUNTY
HOGELAND
TURNER
HAYS
NORTH CHINOOK RESERVOIR
Alkali Lake
Silver Bow Lake
Missouri River
R. 17E
R. 18E
R. 19E
R. 20E
R. 21E
R. 22E
R. 23E
R. 24E
R. 25E
R. 26E
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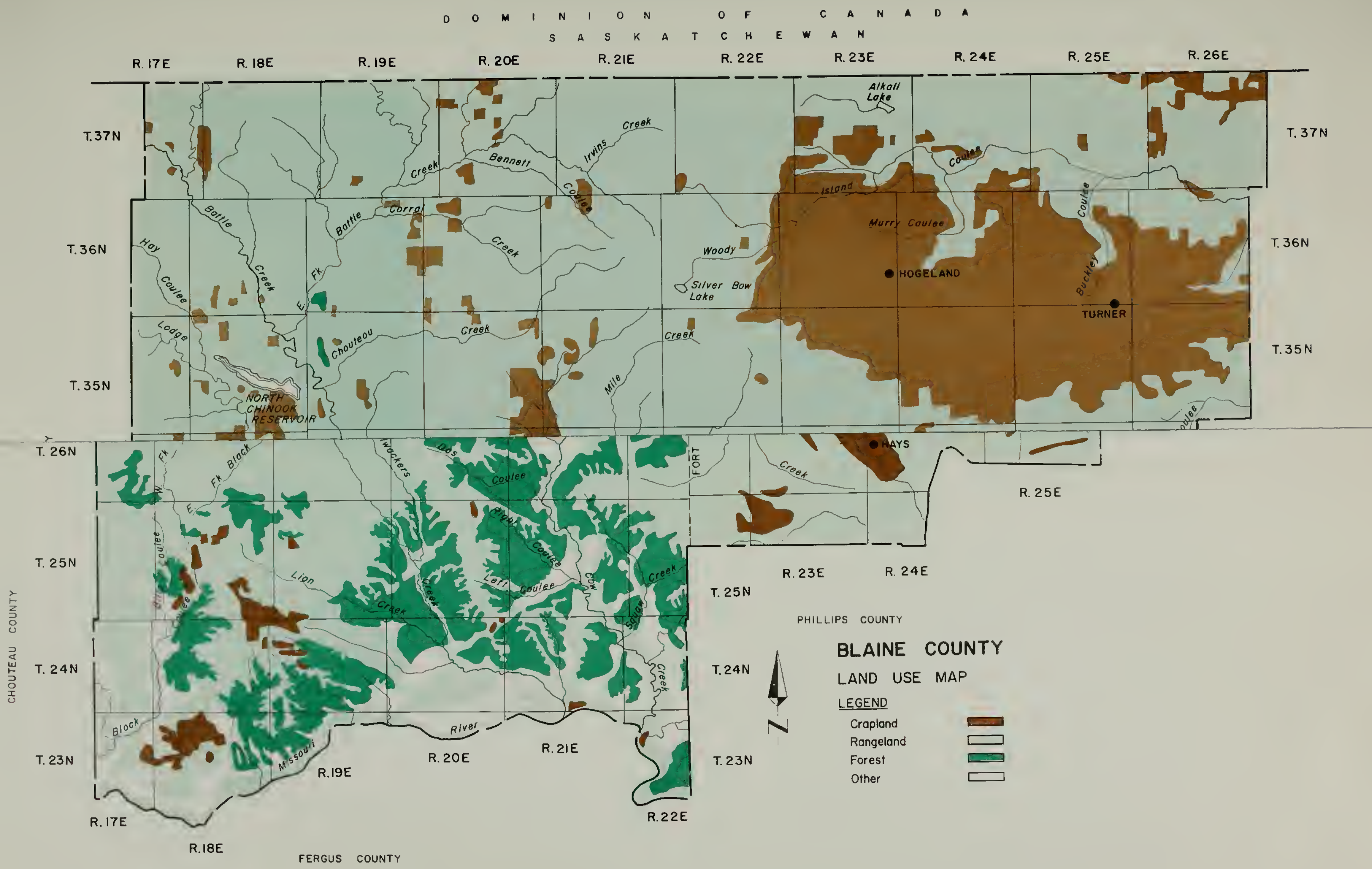

DOMINION OF CANADA
SASKATCHEWAN
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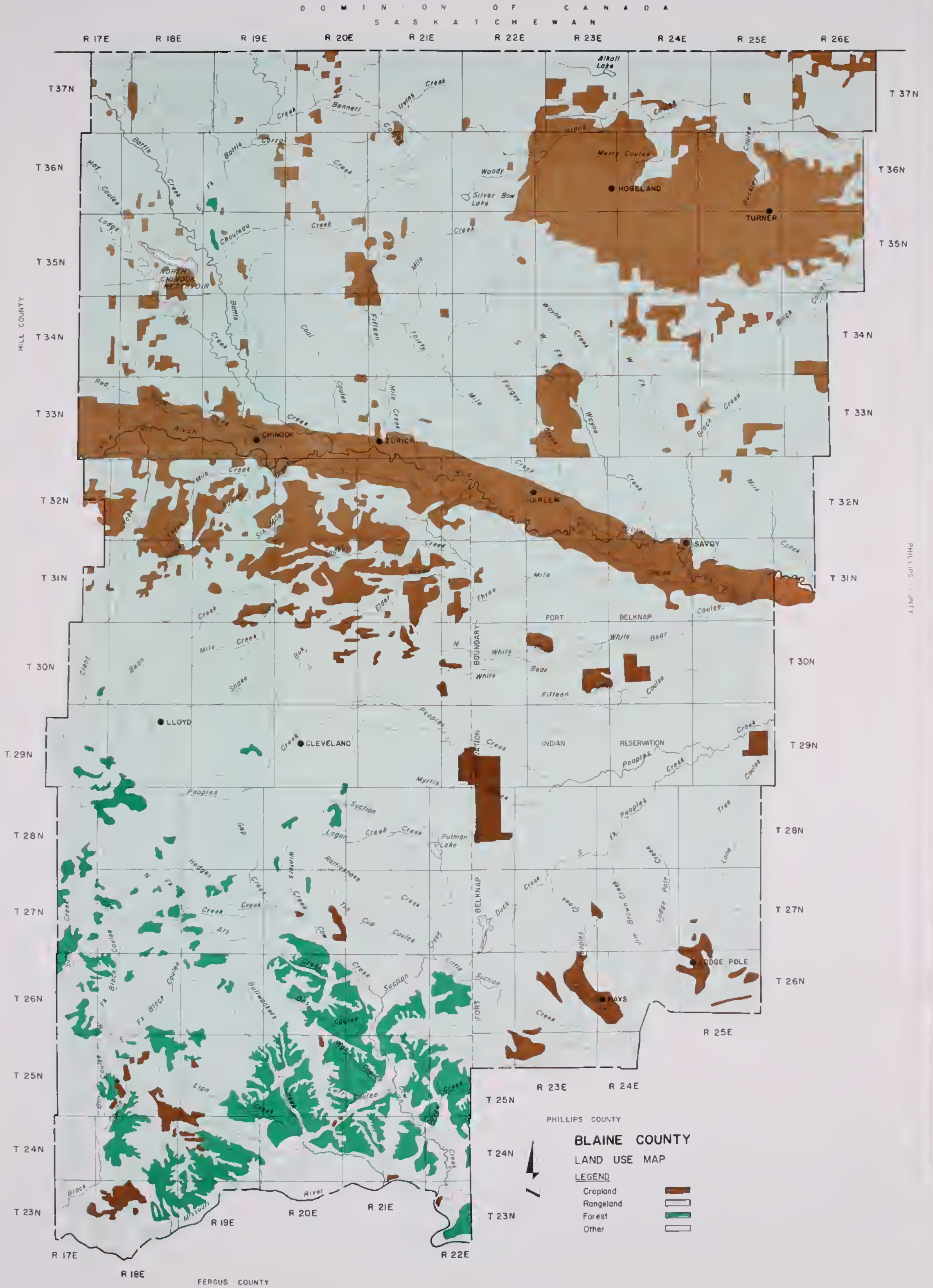
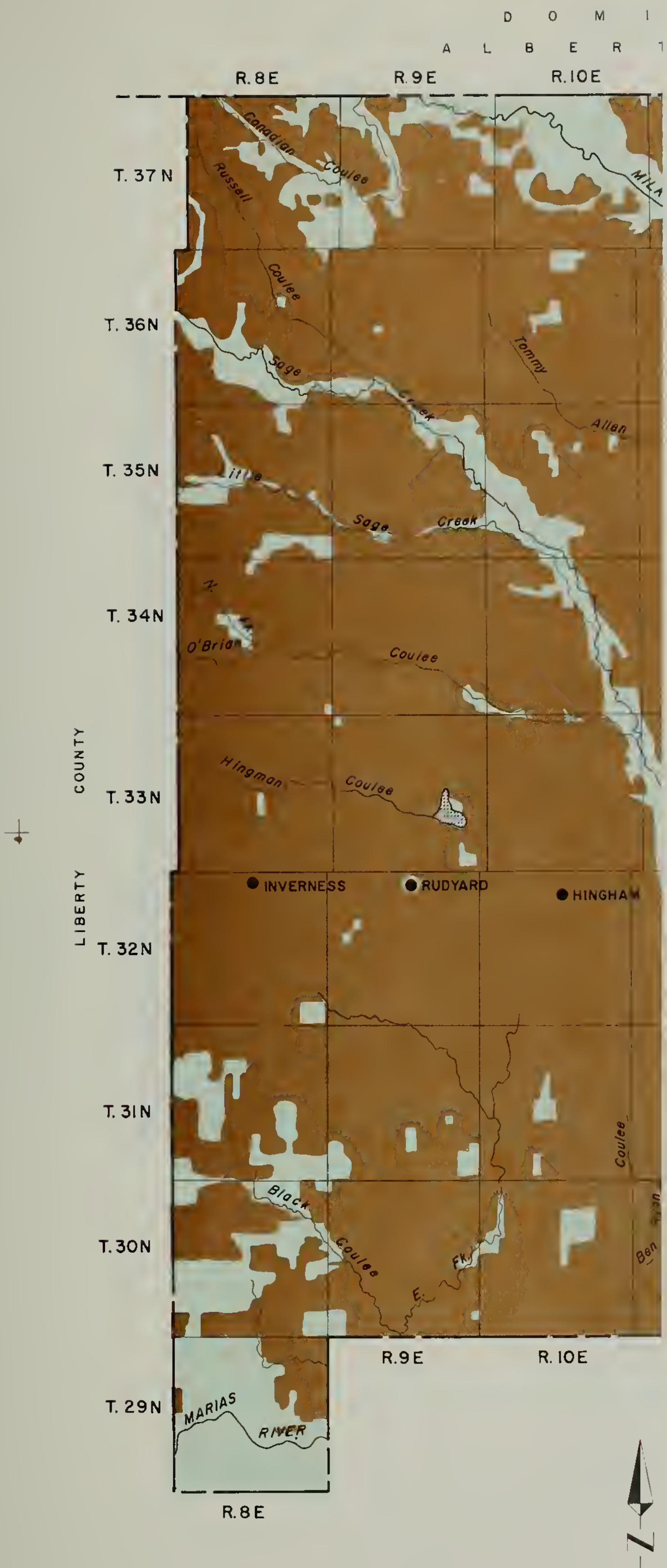
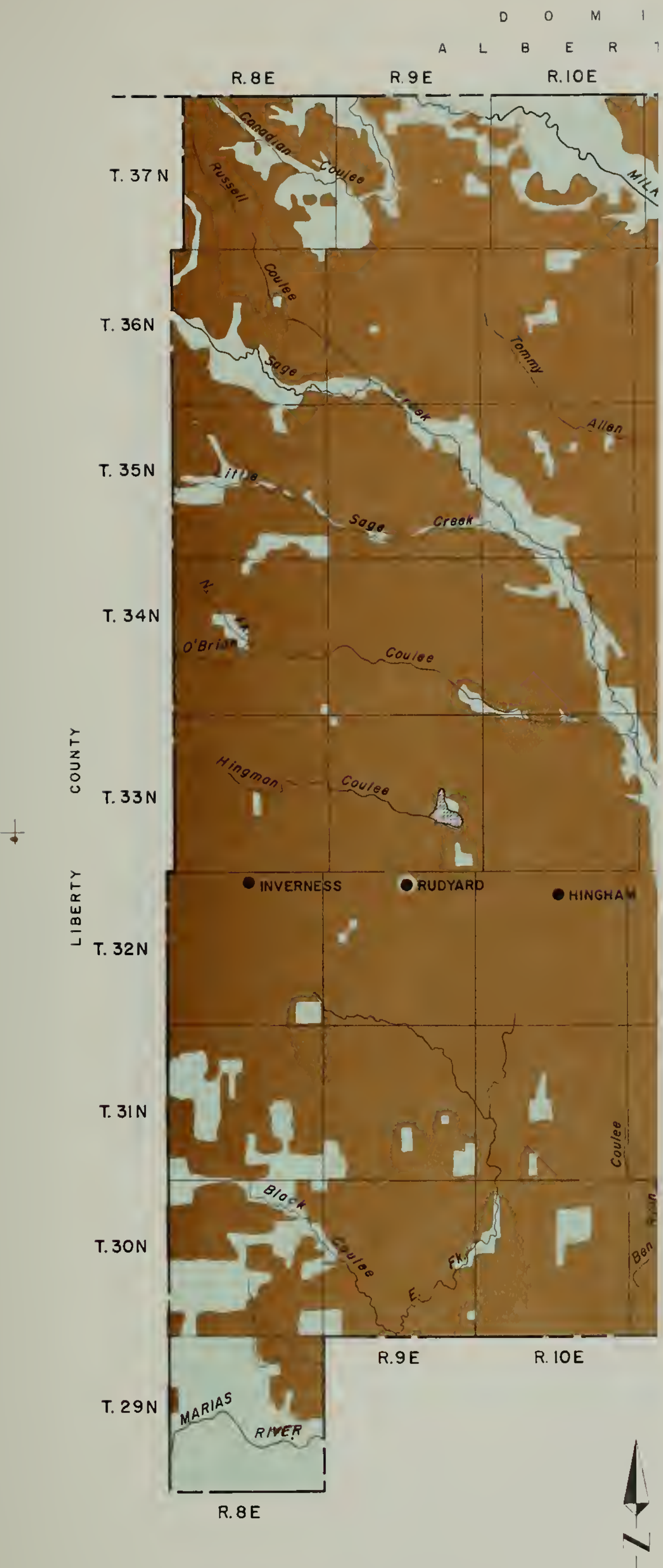
R. 21E
R. 22E
R. 23E
R. 24E
R. 25E
R. 26E
T. 37N
T. 36N
T. 35N
T. 26N
T. 25N
T. 24N
T. 23N
Alkali Lake
Irvins Creek
Bennett Creek
Coulee
Island Coulee
Murry Coulee
Buckley Coulee
HOGELAND
TURNER
HAYS
Woody
Silver Bow Lake
Battle Creek
Corral
Hay Coulee
Lodge
Chouteau Creek
Mile Creek
E. Fk
NORTH CHINOOK RESERVOIR
Dog Coulee
Right Coulee
Left Coulee
Cow Creek
Squaw Creek
Lion Creek
Bullwhackers Creek
W. Fk Black Coulee
E. Fk
FORT
Missouri River
Black Coulee
PHILLIPS COUNTY
FERGUS COUNTY
CHOUTEAU COUNTY
BLAINE COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other
N


DOMINION OF CANADA
SASKATCHEWAN
HILL COUNTY
PHILLIPS COUNTY
FERGUS COUNTY
CHINOOK
ZURICH
HARLEM
SAVOY
HOGELAND
TURNER
LLOYD
CLEVELAND
HAYS
LODGE POLE
NORTH CHINOOK RESERVOIR
FORT BELKNAP INDIAN RESERVATION
BLAINE COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other


D O M I
A L B E R T
R. 8 E
R. 9 E
R. 10 E
T. 37 N
T. 36 N
T. 35 N
T. 34 N
T. 33 N
T. 32 N
T. 31 N
T. 30 N
T. 29 N
LIBERTY COUNTY
Canadian
Coulee
Russell
Coulee
MILK
Sage
Creek
Tommy
Allen
Sage
Creek
O'Brien
Coulee
Hingman
Coulee
INVERNESS
RUDYARD
HINGHAM
Coulee
Black
Coulee
Fk.
E.
Ben
MARIAS
RIVER
R. 9 E
R. 10 E
R. 8 E
N



D O M I
A L B E R T
R. 8 E
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T. 32 N
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T. 30 N
T. 29 N
LIBERTY COUNTY
Canadian
Coulee
Russell
Coulee
Sage
Creek
Tommy
Allen
Little
Sage
Creek
MILK
N.
Fk.
O'Brian
Coulee
Hingman
Coulee
INVERNESS
RUDYARD
HINGHAM
Coulee
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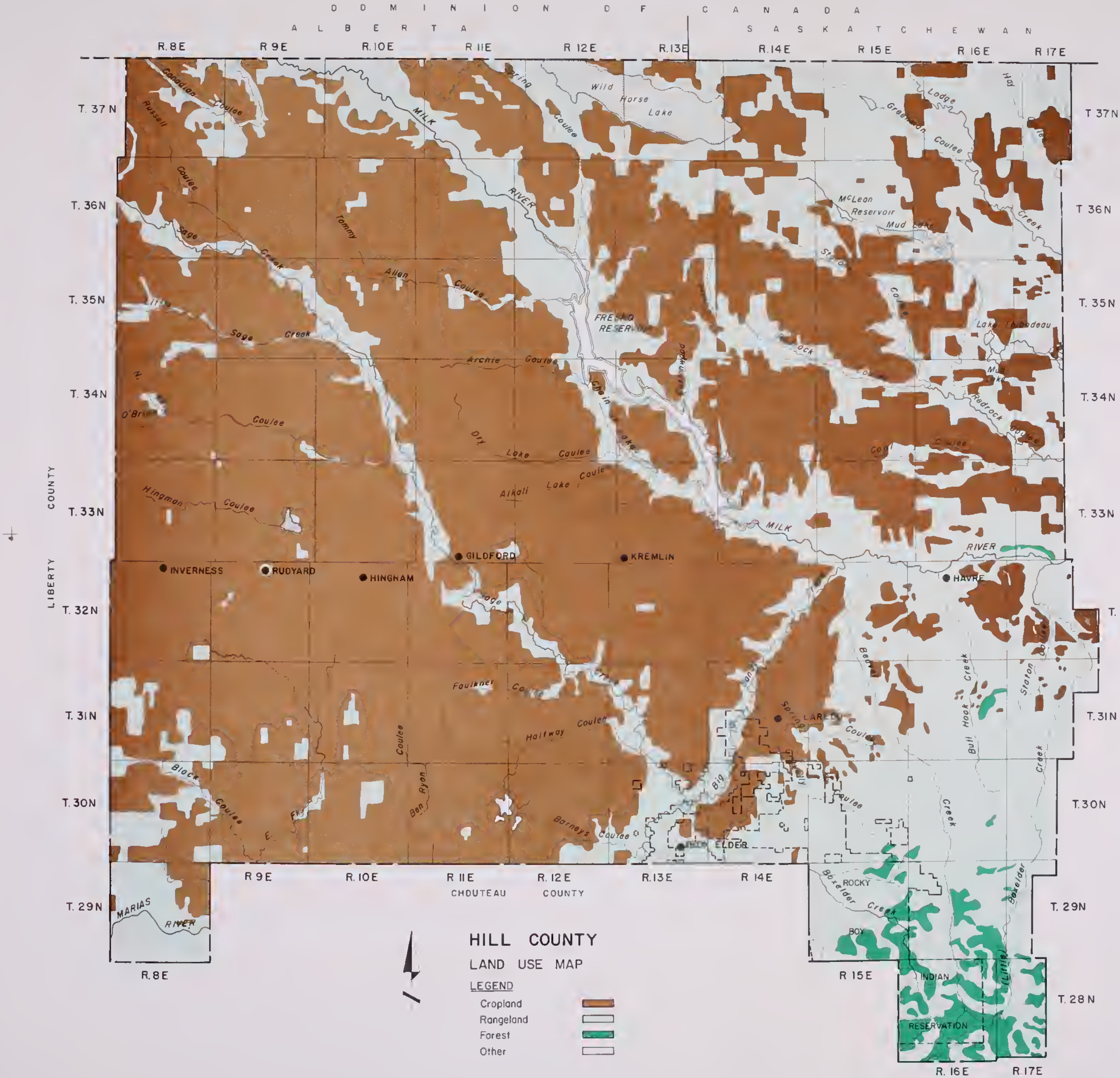
Coulee
Fk.
E.
Ben
MARIAS
RIVER
R. 9 E
R. 10 E
R. 8 E


DOMINION OF CANADA
ALBERTA
SASKATCHEWAN
R. 8 E
R 9 E
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T. 37 N
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T. 35 N
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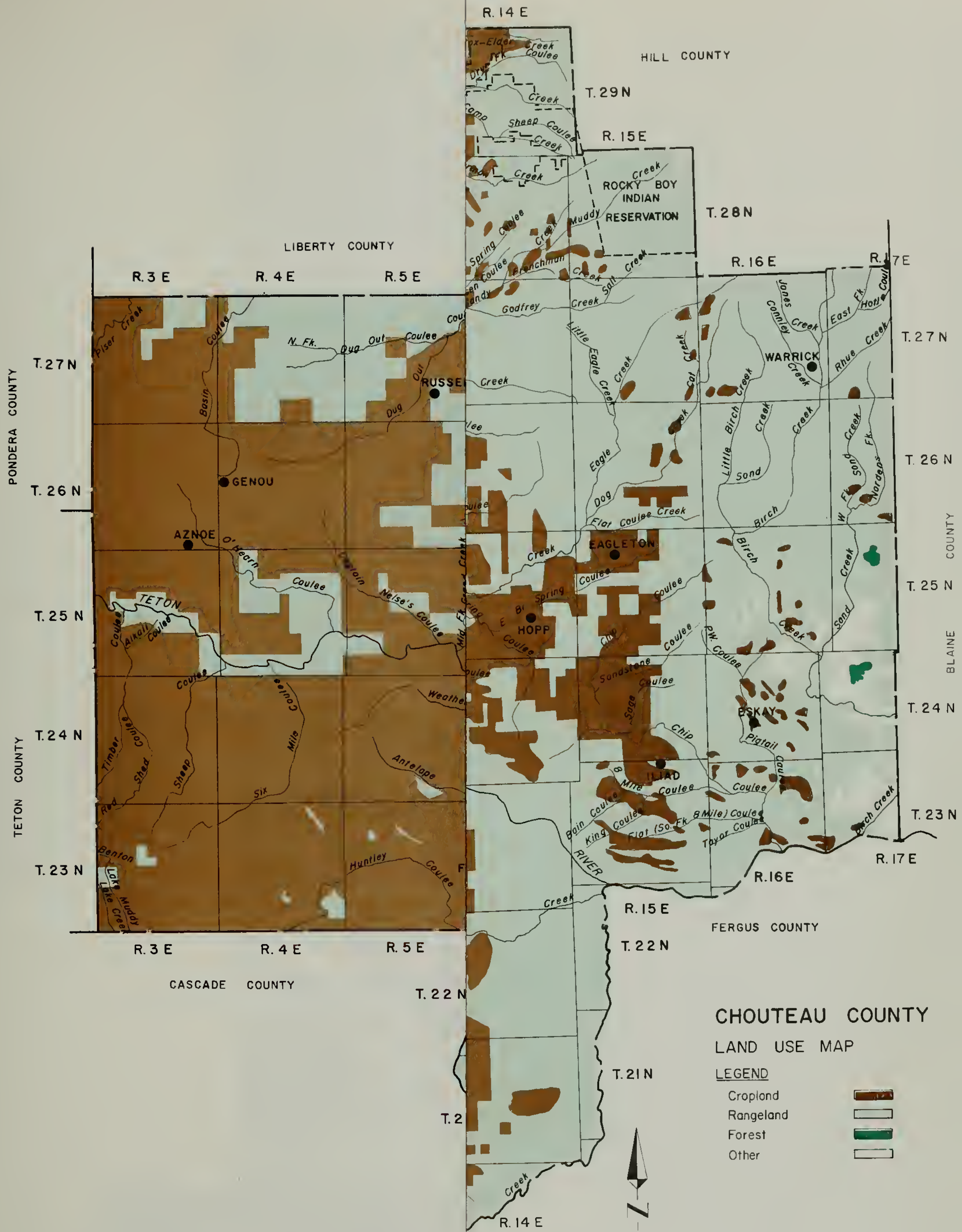
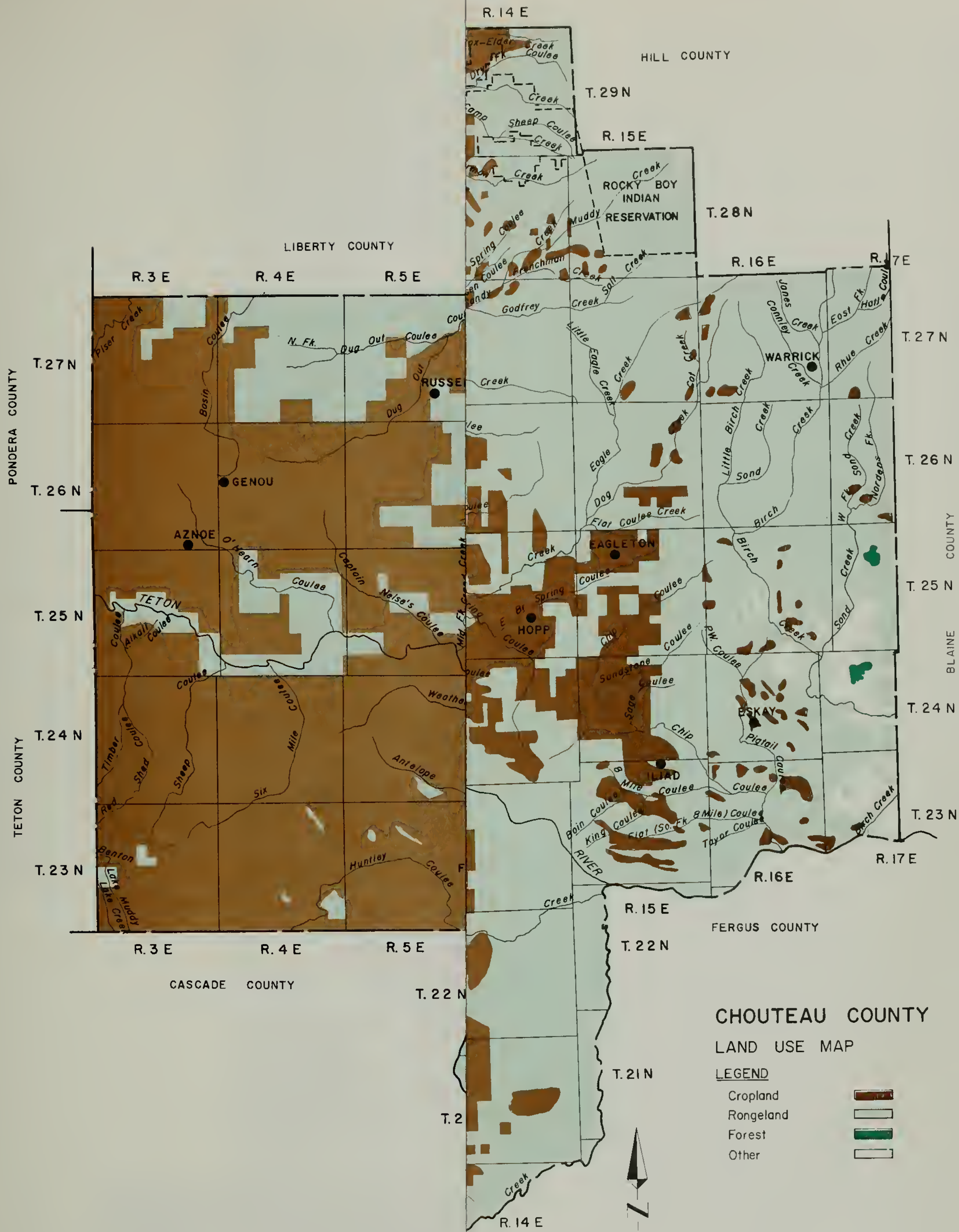
LIBERTY COUNTY
BLAINE COUNTY
CHOUTEAU COUNTY
MILK RIVER
MARIAS RIVER
INVERNESS
RUDYARD
HINGHAM
GILDFORD
KREMLIN
HAVRE
LAREDO
BOX ELDER
ROCKY BOY INDIAN RESERVATION
FRESNO RESERVOIR
McLean Reservoir
Mud Lake
Lake Thibodeau
HILL COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other


CHOUTEAU COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other
HILL COUNTY
LIBERTY COUNTY
PONDERA COUNTY
TETON COUNTY
CASCADE COUNTY
FERGUS COUNTY
BLAINE COUNTY
ROCKY BOY INDIAN RESERVATION
R. 3 E
R. 4 E
R. 5 E
R. 14 E
R. 15 E
R. 16 E
R. 17 E
T. 21 N
T. 22 N
T. 23 N
T. 24 N
T. 25 N
T. 26 N
T. 27 N
T. 28 N
T. 29 N
RUSSEL
GENOU
AZNOE
EAGLETON
HOPP
ESKAY
ILIAD
WARRICK
TETON
RIVER


CHOUTEAU COUNTY
LAND USE MAP
LEGEND
Cropland
Rongeland
Forest
Other
HILL COUNTY
LIBERTY COUNTY
PONDERA COUNTY
TETON COUNTY
CASCADE COUNTY
FERGUS COUNTY
BLAINE COUNTY
ROCKY BOY INDIAN RESERVATION
RUSSEL
GENOU
AZNOE
HOPP
EAGLETON
WARRICK
ESKAY
ILIAD
TETON
RIVER
R. 3 E
R. 4 E
R. 5 E
R. 14 E
R. 15 E
R. 16 E
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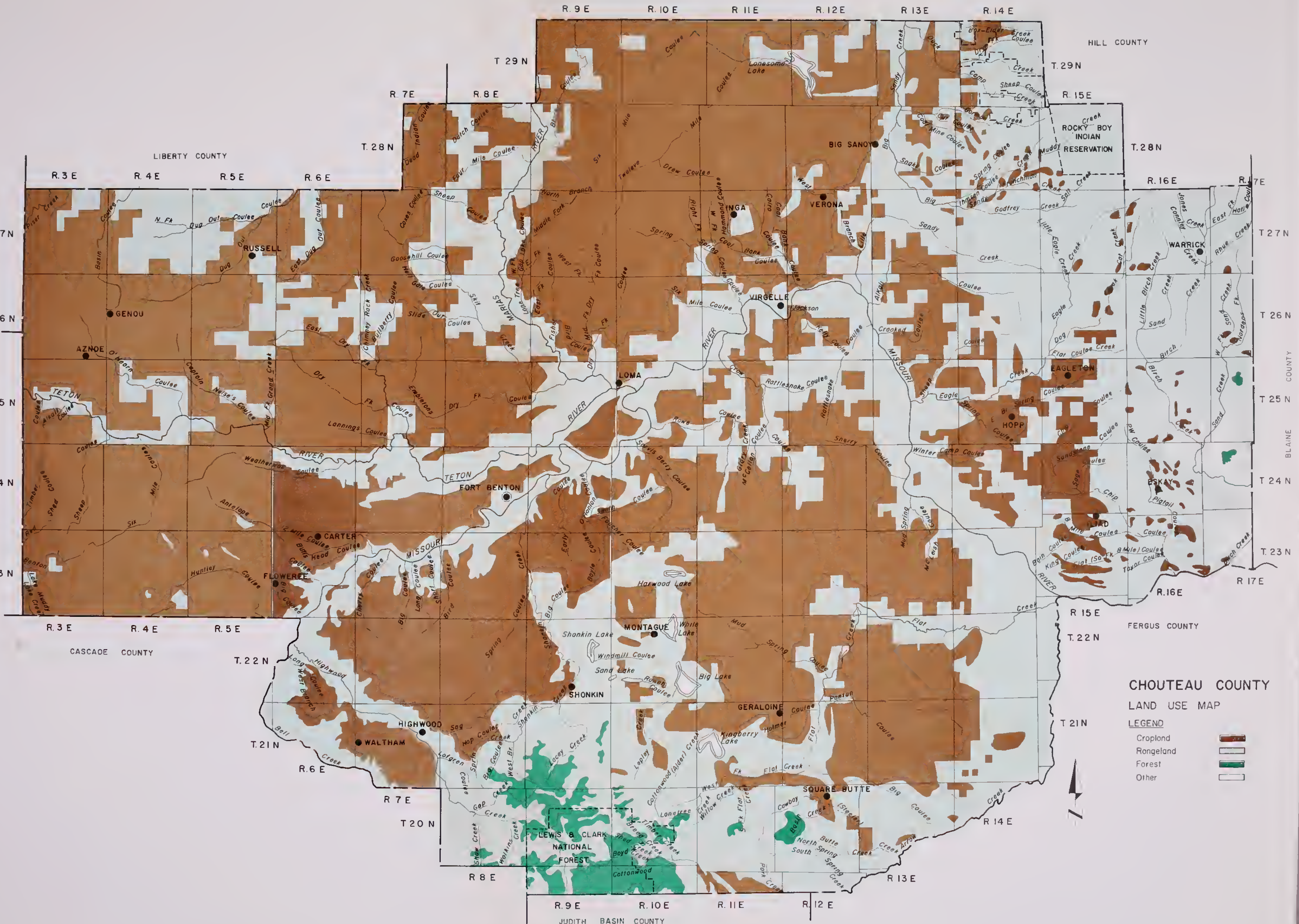
CHOUTEAU COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other
HILL COUNTY
LIBERTY COUNTY
PONDERA COUNTY
TETON COUNTY
CASCADE COUNTY
JUDITH BASIN COUNTY
FERGUS COUNTY
BLAINE COUNTY
ROCKY BOY INDIAN RESERVATION
LEWIS & CLARK NATIONAL FOREST
R.3 E
R.4 E
R.5 E
R.6 E
R.7 E
R.8 E
R.9 E
R.10 E
R.11 E
R.12 E
R.13 E
R.14 E
R.15 E
R.16 E
R.17 E
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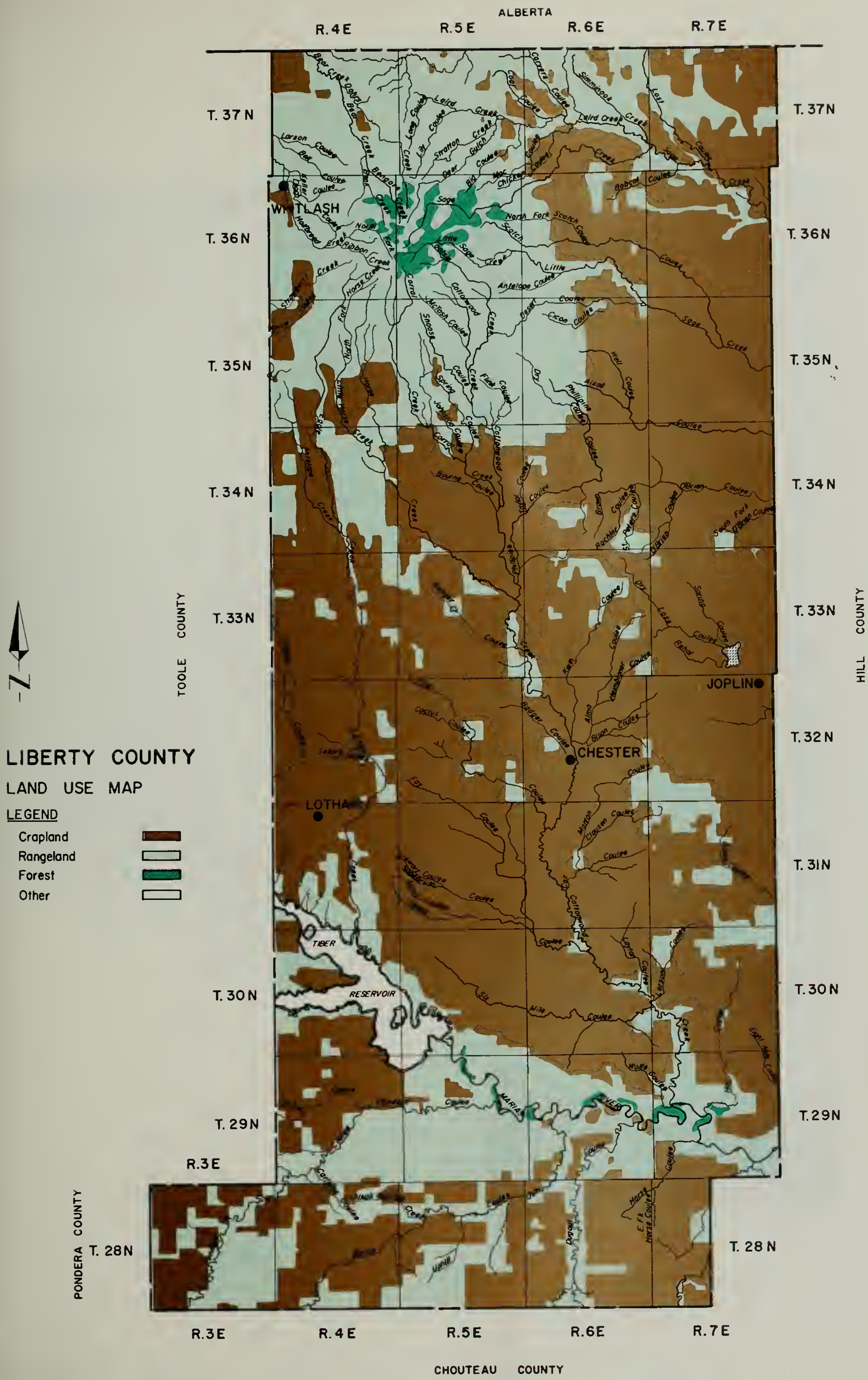
T.28 N
T.27 N
T.26 N
T.25 N
T.24 N
T.23 N
T.22 N
T.21 N
T.20 N
BIG SANDY
VERONA
INGA
RUSSELL
GENOU
AZNOE
VIRGELLE
LOMA
FORT BENTON
CARTER
FLOWEREE
EAGLETON
HOPP
WARRICK
ESKAY
ILIAD
MONTAGUE
SHONKIN
GERALDINE
HIGHWOOD
WALTHAM
SQUARE BUTTE
MISSOURI RIVER
MARIAS RIVER
TETON RIVER
Lonesome Lake
Harwood Lake
Shonkin Lake
White Lake
Sand Lake
Big Lake
Kingberry Lake



ALBERTA
R.4E
R.5E
R.6E
R.7E
T. 37N
T. 36N
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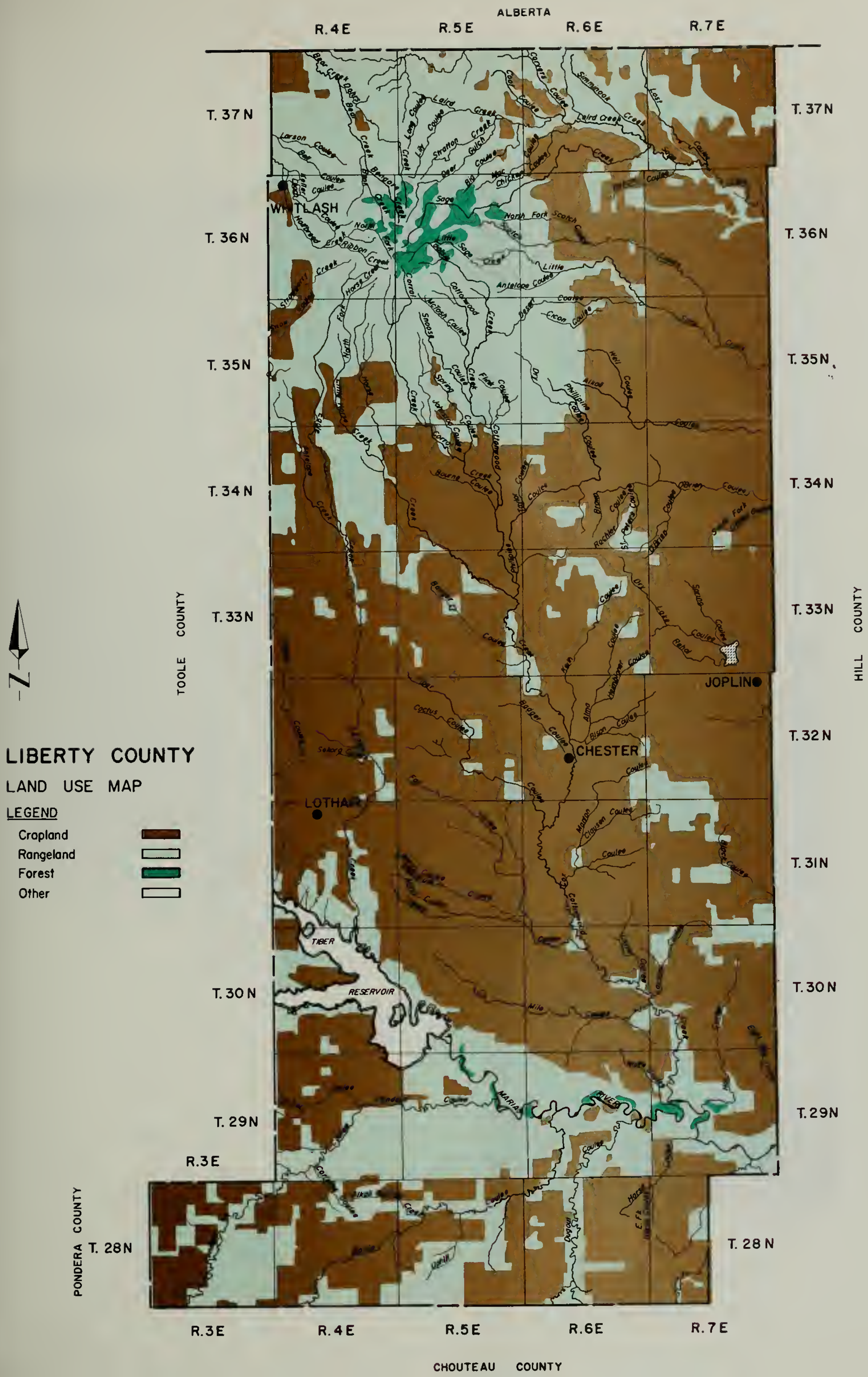
T. 34N
T. 33N
T. 32N
T. 31N
T. 30N
T. 29N
T. 28N
R.3E
WHITLASH
JOPLIN
CHESTER
LOTHAIR
TIBER
RESERVOIR
MARIAS
RIVER
TOOLE COUNTY
HILL COUNTY
PONDERA COUNTY
CHOUTEAU COUNTY
N
LIBERTY COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other


ALBERTA
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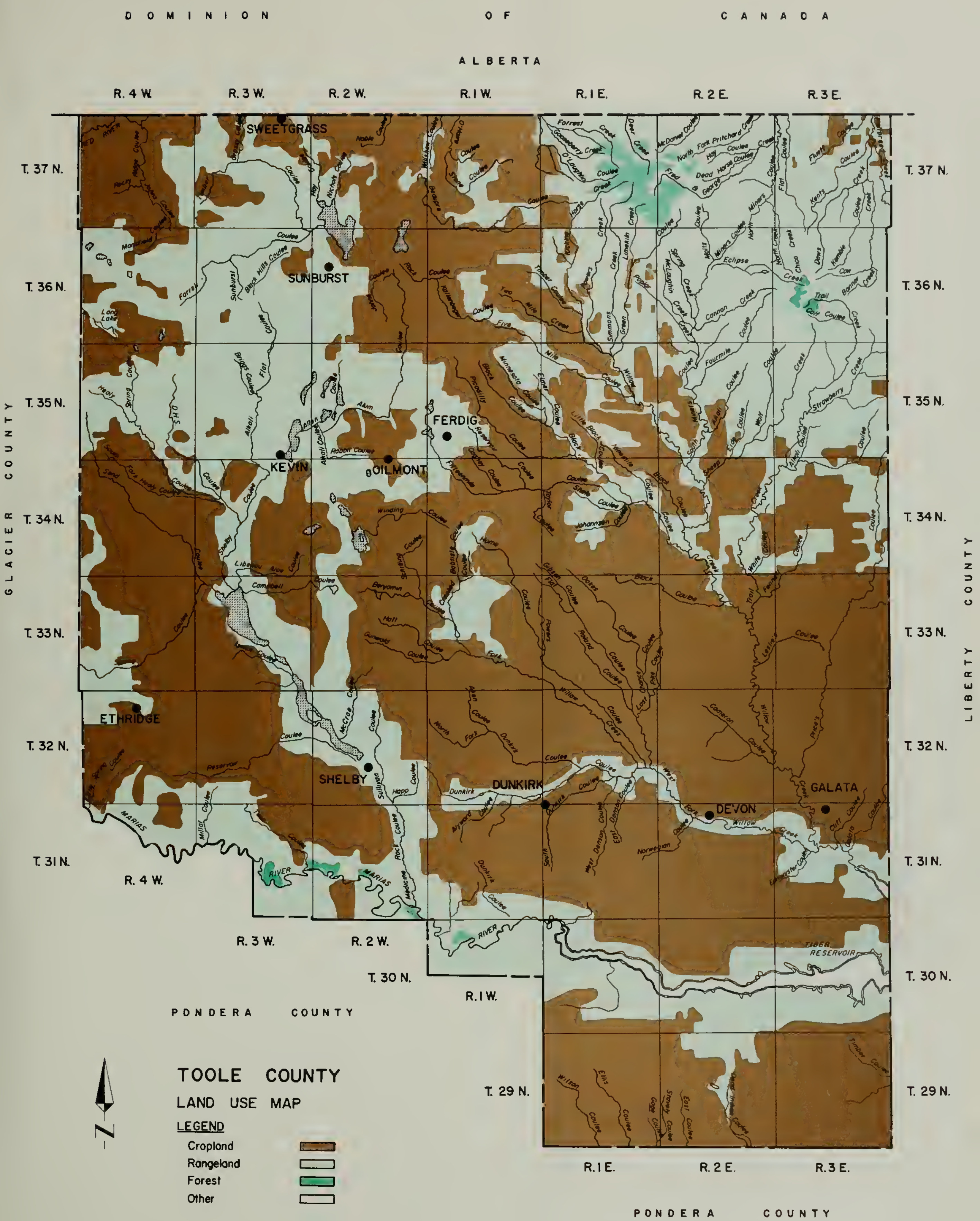
T. 31N
T. 30N
T. 29N
T. 28N
R.3E
TOOLE COUNTY
HILL COUNTY
PONDERA COUNTY
CHOUTEAU COUNTY
WHITLASH
JOPLIN
CHESTER
LOTHAIR
TIBER
RESERVOIR
MARIAS
RIVER
N
LIBERTY COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other


DOMINION OF CANADA
ALBERTA
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R. 1 W.
R. 1 E.
R. 2 E.
R. 3 E.
T. 37 N.
T. 36 N.
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T. 32 N.
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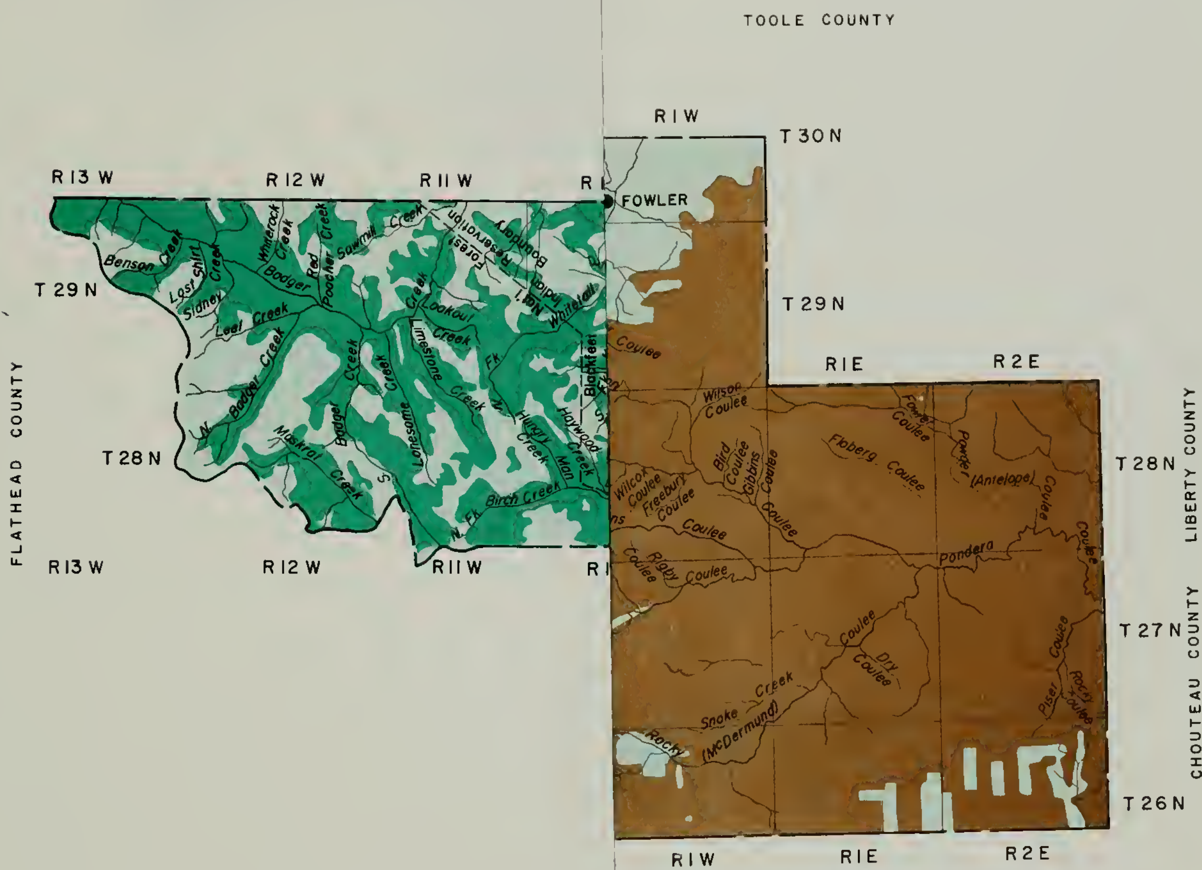
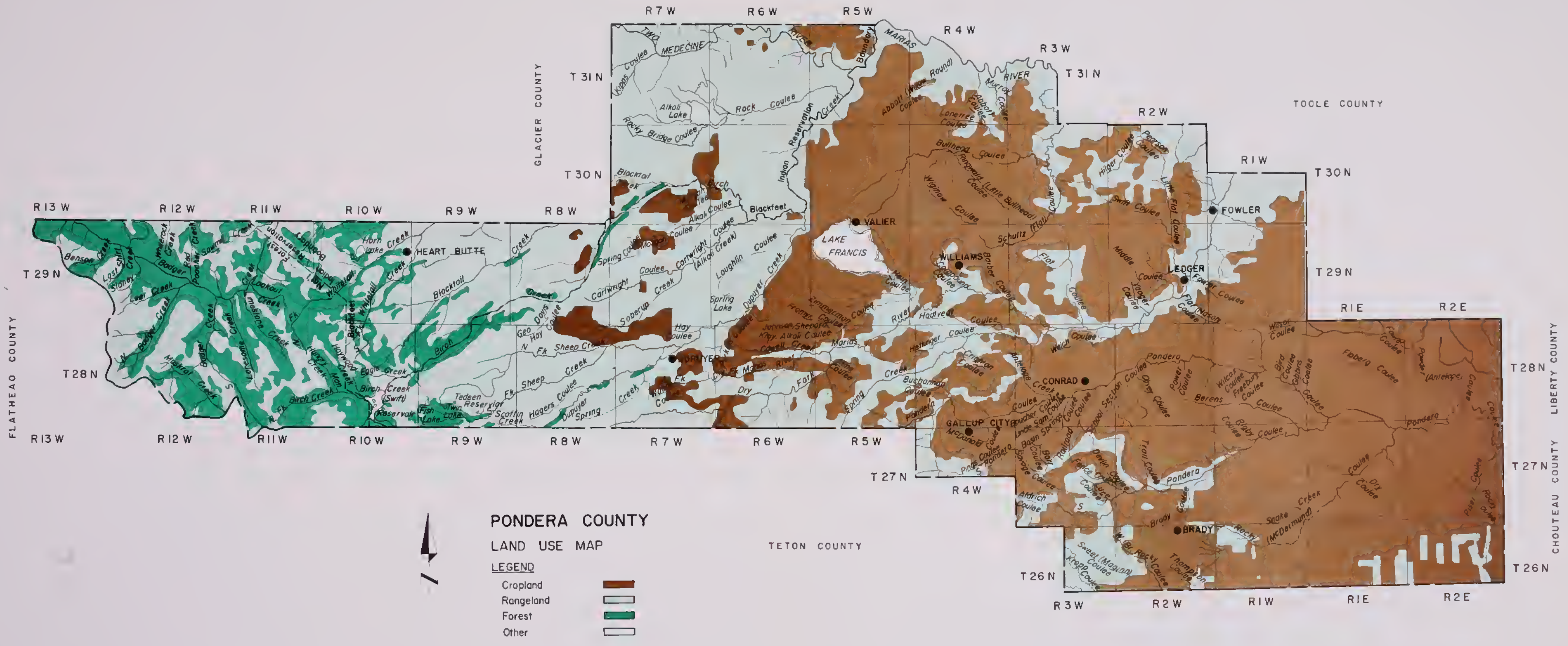
T. 30 N.
T. 29 N.
GLACIER COUNTY
LIBERTY COUNTY
PONDERA COUNTY
SWEETGRASS
SUNBURST
KEVIN
OILMONT
FERDIG
ETHRIDGE
SHELBY
DUNKIRK
DEVON
GALATA
MARIAS
RIVER
TIBER RESERVOIR
TOOLE COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other
N


TOOLE COUNTY
R 1 W
T 30 N
R 13 W
R 12 W
R 11 W
FOWLER
T 29 N
FLATHEAD COUNTY
T 28 N
R 1 E
R 2 E
LIBERTY COUNTY
T 27 N
CHOUTEAU COUNTY
T 26 N
Benson Creek
Lost Shirt
Sidney Creek
Leaf Creek
Whiterock Creek
Badger Creek
Red
Poacher Creek
Sawmill Creek
Forest
Reservation
Boundary
Indian
Lookout Creek
Limestone Creek
Lonesome Creek
Badger Creek
Muskrat Creek
N. Fk.
Birch Creek
Hungry Creek
Haywood Creek
Main
Whitetail
Blackfeet
Coulee
Wilson Coulee
Floberg Coulee
Fowler Coulee
Bird Coulee
Gibbins Coulee
Wilcox Coulee
Freebury Coulee
Rigby Coulee
Pondera
(Antelope)
Dry Coulee
Snake Creek
(McDermund)
Rocky
Piser
Rocky Coulee


PONDERA COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other
GLACIER COUNTY
TOOLE COUNTY
TETON COUNTY
FLATHEAD COUNTY
LIBERTY COUNTY
CHOUTEAU COUNTY
HEART BUTTE
VALIER
LAKE FRANCIS
WILLIAMS
FOWLER
LEDGER
CONRAD
DUPUYER
GALLUP CITY
BRADY
R 13 W
R 12 W
R 11 W
R 10 W
R 9 W
R 8 W
R 7 W
R 6 W
R 5 W
R 4 W
R 3 W
R 2 W
R 1 W
R 1 E
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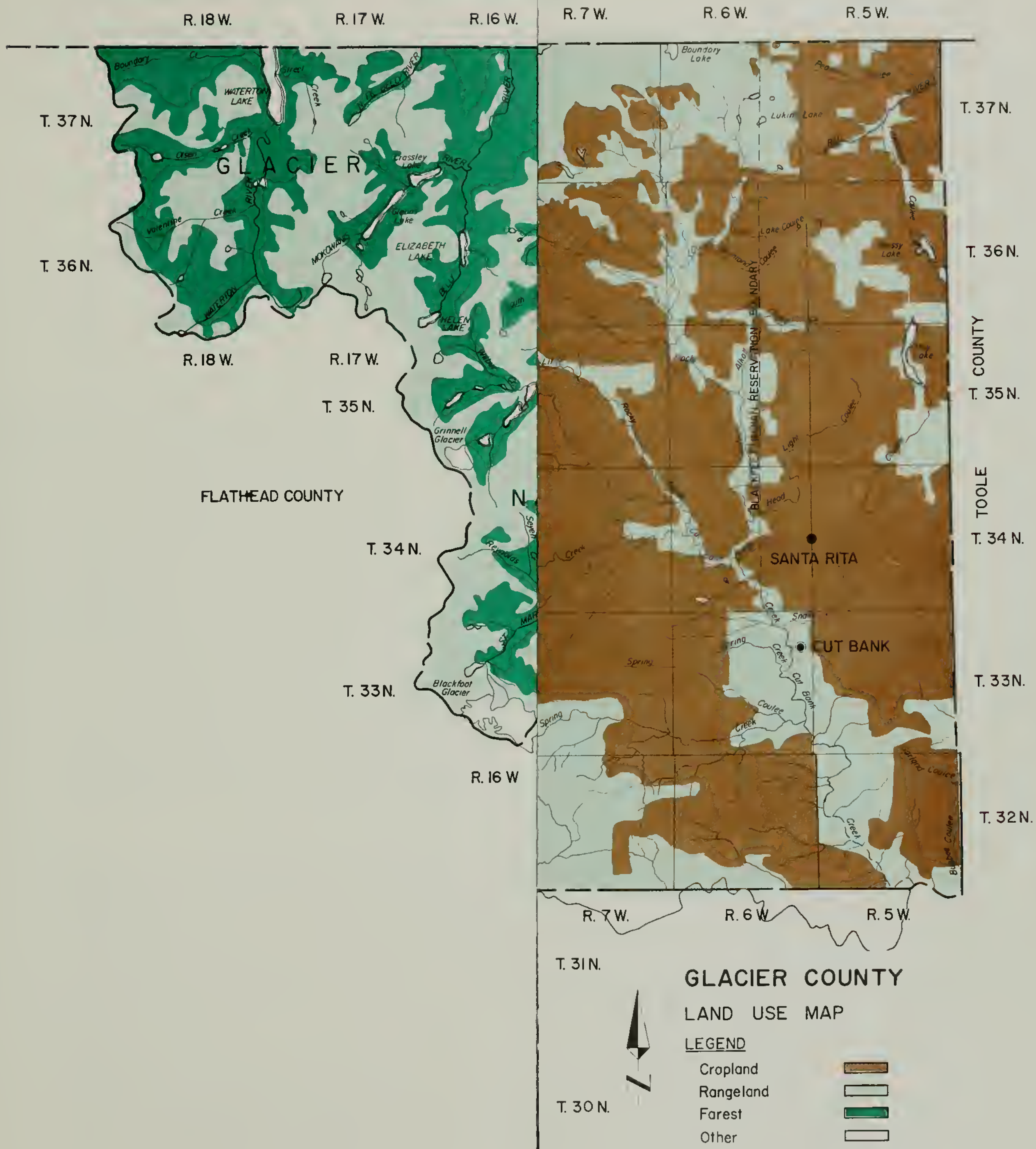
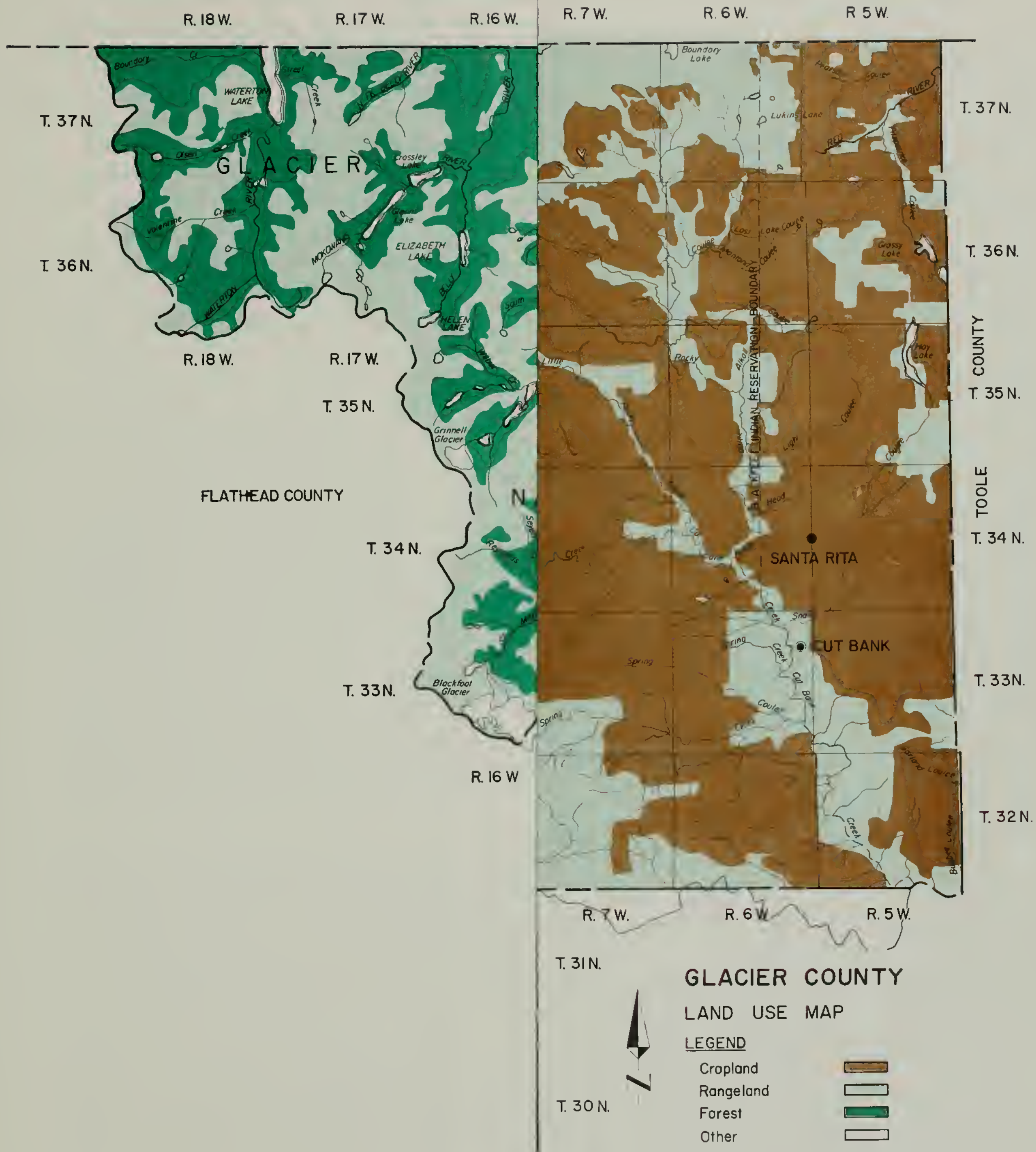
T 31 N
T 30 N
T 29 N
T 28 N
T 27 N
T 26 N
Blackfeet Indian Reservation
Marias River
Birch Creek
Dupuyer Creek
Pondera Coulee
Two Medecine River
Badger Creek


GLACIER COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other
R. 18 W.
R. 17 W.
R. 16 W.
R. 7 W.
R. 6 W.
R. 5 W.
T. 37 N.
T. 36 N.
T. 35 N.
T. 34 N.
T. 33 N.
T. 32 N.
T. 31 N.
T. 30 N.
FLATHEAD COUNTY
TOOLE COUNTY
SANTA RITA
CUT BANK
GLACIER
BLACKFEET INDIAN RESERVATION BOUNDARY
WATERTON LAKE
ELIZABETH LAKE
HELEN LAKE
Grinnell Glacier
Blackfoot Glacier
Boundary Lake
Lukin Lake



R. 18 W.
R. 17 W.
R. 16 W.
R. 7 W.
R. 6 W.
R 5 W.
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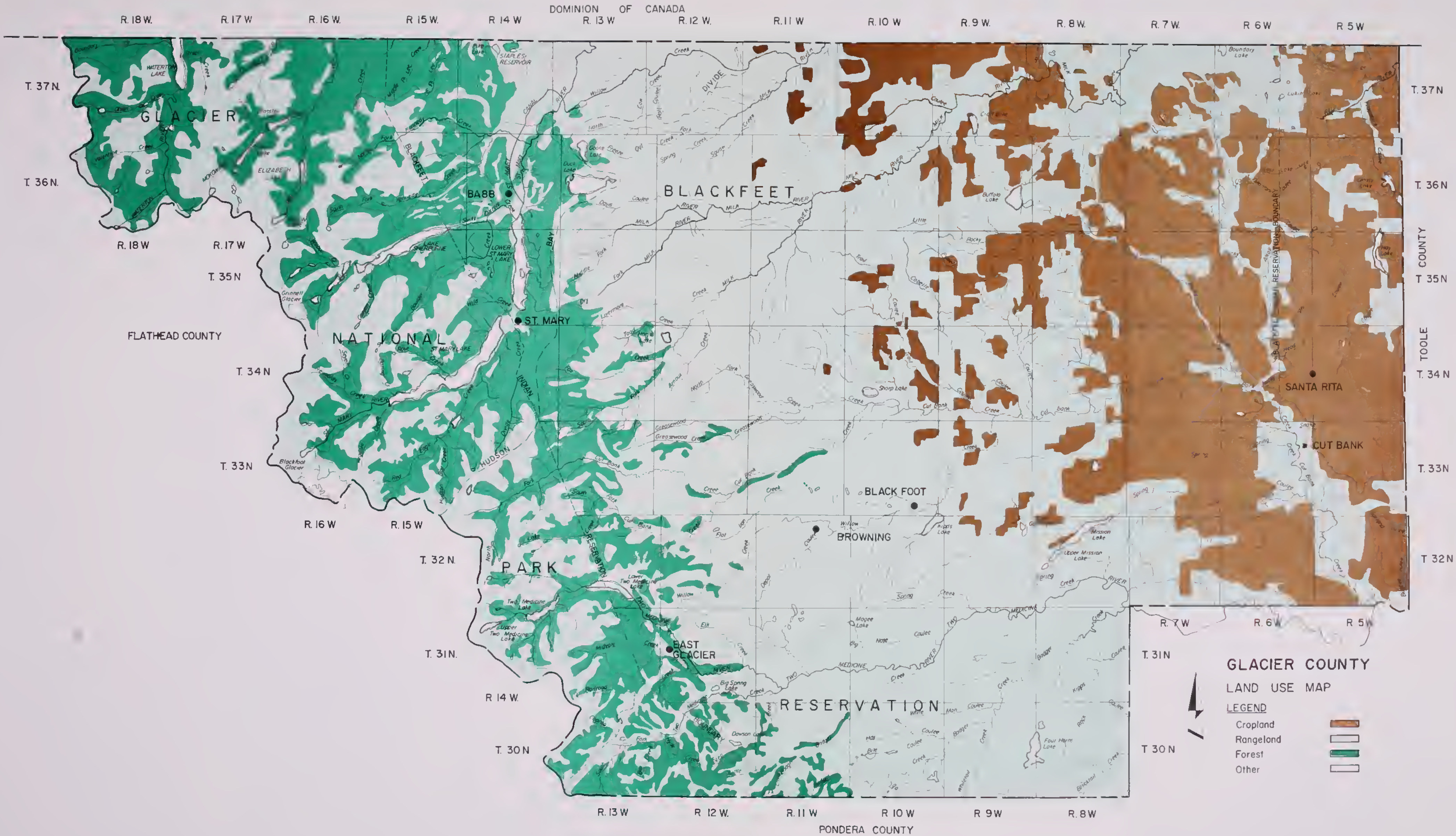
T. 36 N.
T. 35 N.
T. 34 N.
T. 33 N.
T. 32 N.
T. 31 N.
T. 30 N.
R. 16 W
GLACIER
N
FLATHEAD COUNTY
TOOLE COUNTY
BLACKFEET INDIAN RESERVATION BOUNDARY
WATERTON LAKE
ELIZABETH LAKE
HELEN LAKE
Grinnell Glacier
Blackfoot Glacier
Boundary Lake
Lukins Lake
Grassy Lake
SANTA RITA
CUT BANK
GLACIER COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other



DOMINION OF CANADA
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R. 12 W.
R. 11 W
R. 10 W
R. 9 W.
R. 8 W.
R. 7 W.
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R. 5 W
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T. 32 N.
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GLACIER
NATIONAL
PARK
BLACKFEET
RESERVATION
FLATHEAD COUNTY
TOOLE COUNTY
PONDERA COUNTY
BABB
ST. MARY
BLACK FOOT
BROWNING
EAST GLACIER
SANTA RITA
CUT BANK
GLACIER COUNTY
LAND USE MAP
LEGEND
Cropland
Rangeland
Forest
Other

The probable effects new irrigated lands will have on existing land use are discussed in Part IV of this report. In general, it can be said that something like 380,000 acres of present dryland could be irrigated with the available supply of water (see Part X). This is a small part of the total 18,761,000 acres in the Study Area and it seems logical to conclude that most of the land will continue under its present usage. Of the new irrigation land, it is estimated that approximately 70% will be land which is presently dry farmed. The rest will come from rangeland.

As might be expected, some of the proposed new irrigated lands in Valley, Phillips, Blaine and Glacier counties would come from rangeland. The new irrigated acreage in the remainder of the area would largely come from dry cropland.

F. DRYLAND PROBLEM - SOUR FALLOW

Sour fallow is land which has become seeped and saline and, as a result, is no longer suitable for growing crops. It is caused primarily by the practice of summer fallow with control of weeds and conservation of moisture. Factors which contribute to the problem are salts in the subsoil and lower strata and the presence of impermeable layers at relatively shallow depth.[2]

As precipitation percolates through the soil it dissolves soluble salts and becomes saline. When the soil is underlain with an impermeable layer, a water table develops and water flows away from the area following the slope of the impermeable layer. These are "recharge" or "contributing" areas.[3]

This moving, saline water eventually reaches an area where it is close enough to the surface to keep the surface wet. This is a "discharge" or "problem" area. Over a period of years, water continues to move into the problem areas, carrying a heavy load of salts, and eventually the area becomes too salty for continued plant growth.

The problem is not particularly new, but it is developing at an alarming rate. It is estimated that the acreage of sour soils is increasing 10 to 15 percent each year. Based on information collected in early 1969, Table III-3 shows the estimated acres of sour fallow land and the acres contributing to the problem areas.

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Table III-3

County	Acres of Wet & Saline Soils	Acres Contributing to Wet & Saline Soil Areas
Valley	250	10,000
Phillips	300	20,000
Blaine	400	30,000
Hill	900	15,000
Chouteau	9,000	270,000
Liberty	200	10,000
Toole	1,500	3,000
Pondera	1,500	3,000
Glacier	2,000	4,000
Total 9 County Study Area	16,050	377,000

It is now felt that the figures were even conservative for early 1969 when the survey was made. Current figures show a considerably greater extent of the problem than indicated here.

There is an urgent need for a system of farming that will use each year's precipitation currently - hopefully in a manner economically comparable to the alternate small grain and fallow system presently being practiced.

If this cannot be done, then a program must be found which will encourage and enable owners and operators of both problem and contributing areas to make needed changes in their system of farming with the least possible sacrifice of income and land values. Considering the permanence of the damage being wrought, and the rate at which it is growing, this is the Study Area's most urgent conservation problem on non-irrigated cropland.

Research on the problem was begun in 1969 and is continuing. Owners and operators on the Highwood Bench and surrounding area formed the Chouteau County Alkali Control Association in early 1969. A conservancy district could provide a coordinated effort for research and eventual solution of this problem which is beginning to plague many of the dryland farmers of the area.

FOOTNOTES - PART III

[1] In several counties, land use information was supplied by the Agricultural Stabilization and Conservation Service.

[2] "The Story of Sour Fallow - Montana's Most Urgent Conservation Problem on Non-Irrigated Cropland," by Wendell Thacker and Dr. Hayden Ferguson, Montana Resource Development Committee, October 1970.

[3] Data from Montana Farmer-Stockman article which reported the results of a survey made by Clair Clark with the Soil Conservation Service in Great Falls.

PART IV - ECONOMY OF STUDY AREA

PART IV

ECONOMY OF STUDY AREA

A. NON-AGRICULTURAL ECONOMY

The non-agricultural economy of North Central Montana is generally of limited significance. Manufacturing accounts for very little employment or value added to the economy. Only Hill and Valley Counties have significant manufacturing and in both cases the total value added by manufacturing is less than four percent (4%) of the total aggregate income.[1] Mining is more important in the western counties, however, agriculture is again of overwhelming importance in every instance with the exception of Glacier County. Glacier County derives almost as much income from its mineral industry (natural gas) as it does from agriculture.[2]

An examination of the numbers of retail, wholesale and service establishments and of the sales in each of those sectors reveals that although there has been a general decrease in the numbers of establishments, sales have been increasing. Only Phillips County has experienced a decline in sales in all three sectors. Table IV-1 shows the change from 1963 to 1967 by county. Hill County stands out as a major trade center in every sector with Valley County also being a major center. It is interesting to note that although Chouteau County is among the lowest in retail and service sales, it is the second highest in wholesale sales. Apparently, its proximity to Great Falls has allowed it to become a major wholesale distribution center for much of the area. It should also be noted that Glacier County is the leading county in terms of both the number of service establishments and the amount of sales. This is largely a result of the large tourist business connected with Glacier National Park.

In most cases the non-agricultural economy is directly or indirectly related to the servicing and maintenance of the extensive agricultural economy which is discussed in the following section.

Government has played a significant role in the past and will continue to do so in the future. The operation of two major air force bases in and near the district has had a great economic impact in the past. The closing of one of those bases at Glasgow was a tremendous economic shock to Valley County and the surrounding areas. Other government defense activities have had a similar if less dramatic effect in the past and may again in the near future. Plans to build a massive anti-ballistic missile system in the area will provide temporary employment, but will also require greatly expanded social services. The important factor about these government programs is that although they have tremendous impact on the area, they are controlled completely from outside of the area. Whether they are a stimulant or a depressant in the long run is not within the power of the local people.

Numbers refer to footnotes located at the end of this chapter.

TABLE IV - I

WHOLESALE, RETAIL & SERVICE TRADE IN NORTH CENTRAL CONSERVANCY DISTRICT

	Retail				Wholesale				Services			
	1963		1967		1963		1967		1963		1967	
	Estab.	Sales ($1000)	Estab.	Sales ($1000)	Estab.	Sales ($1000)	Estab.	Sales ($1000)	Estab.	Sales ($1000)	Estab.	Sales ($1000)
Blaine	90	8,482	83	8,880	16	5,071	16	7,171	24	379	32	468
Chouteau	82	7,658	71	7,311	45	10,781	41	26,025	29	470	27	488
Glacier	135	13,787	141	17,043	25	8,382	23	16,338	71	2,132	96	3,565
Hill	175	24,427	171	32,505	55	34,529	47	36,820	91	2,651	77	2,159
Liberty	33	4,030	29	5,270	16	5,966	11	7,619	10	99	12	152
Phillips	103	8,521	82	8,268	17	4,396	14	2,772	41	652	26	523
Pondera	95	11,130	9	14,674	32	10,192	28	19,035	31	513	42	587
Toole	113	9,178	100	9,469	29	11,143	23	15,585	50	858	54	1,002
Valley	161	21,860	152	21,408	38	19,011	36	22,037	81	1,691	70	1,360
Conservancy District	987	109,073	922	124,828	273	115,471	239	153,402	428	9,445	436	10,304

Source: 1967 ensus of Business, U. S. Department of Commerce, Bureau of the Census.

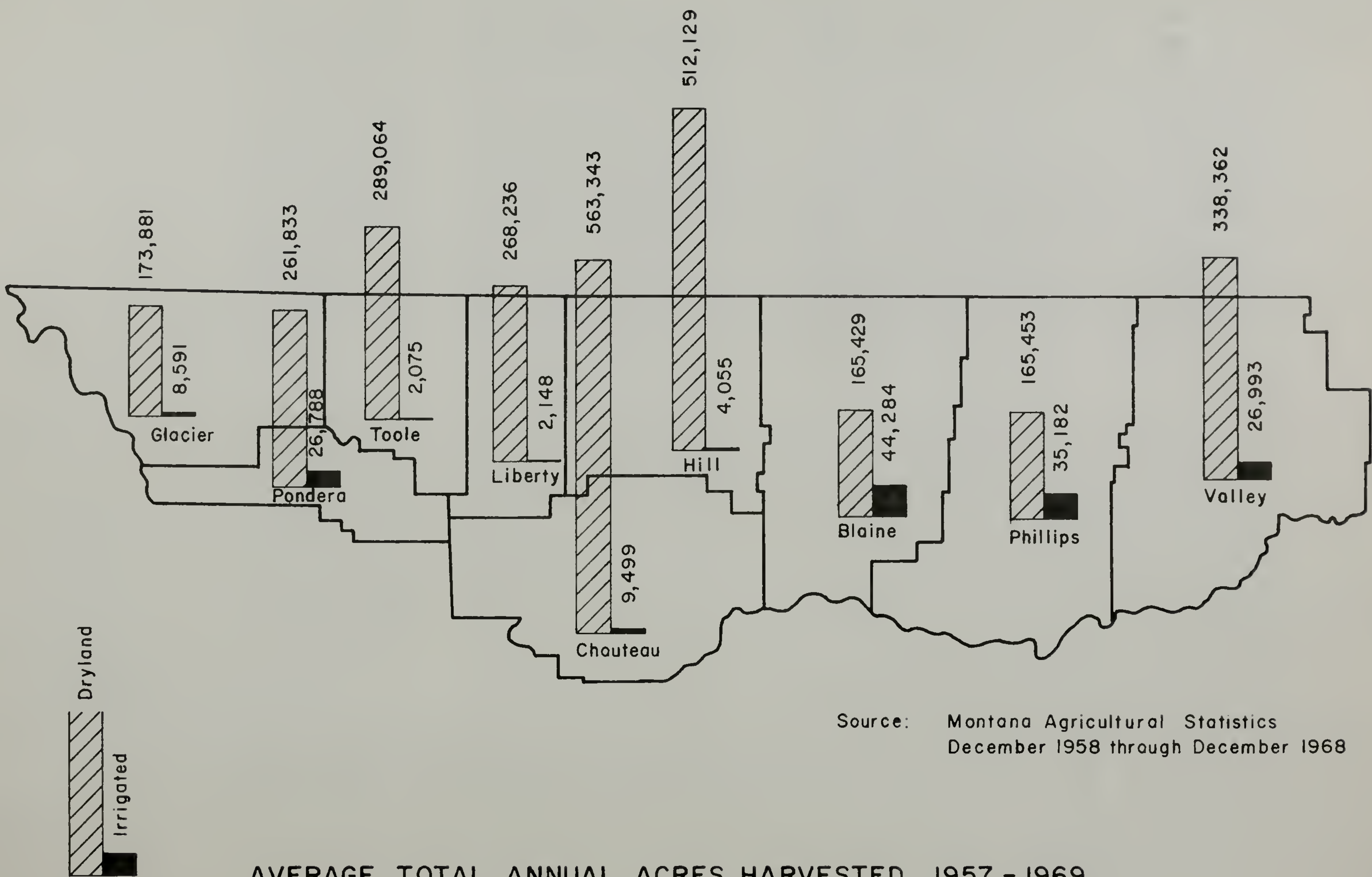
Other government activities in the Study Area have also had an influence. The National Park Service has been of significant importance in the Glacier Park area. Fort Peck Reservoir, a federal project, is very important in the eastern counties. The location of a unit of the State University System in Havre is important to that city and most of the area.

B. AGRICULTURAL ECONOMY

The agricultural economy of the Study Area can be broken down into identifiable sections based on livestock and cash crop production. The three eastern counties rely predominantly on livestock production while the western counties depend mostly on crop production. The three eastern counties also have the majority of the irrigated cropland. The western counties are almost entirely dryland with the exception of Pondera County which does have over 124,000 acres of irrigated land. The area does not break down as easily in terms of the types of crops produced, although wheat production is concentrated in the central counties and feed grains such as barley and oats are more significant in the major livestock counties.

Two major trends in the agriculture of the area are important to an understanding of what is likely to develop in the future. As recently as 1956, wheat production accounted for 67 percent of total cash receipts of farms in the district. By 1967 that figure had declined to 55 percent of total cash receipts. Although wheat is still of major importance to the area, the trend away from total dependence on wheat can only help to benefit the area in view of the current wheat market and the problems which accompany a single crop economy. While wheat has been decreasing in importance, livestock production has been increasing in terms of percentage of total cash receipts. In 1956 livestock accounted for 20 percent of total cash receipts to farms, by 1967 that figure had reached 34 percent.[3]

1. Crops. Figure IV-1 shows the amount of irrigated and dry cropland in each county. Four counties - Blaine, Phillips, Valley and Pondera - contain 84 percent of the total irrigated acres. For the area as a whole, however, irrigated cropland amounts to only 5.5 percent of of the total acreage in crops. Chouteau and Hill Counties are the most important crop producers accounting for 38 percent of the total cropland of the area.



Source: Montana Agricultural Statistics
December 1958 through December 1968

AVERAGE TOTAL ANNUAL ACRES HARVESTED, 1957 - 1969

FIGURE IV - I

Table IV-2 itemizes the irrigated and dry croplands according to the type of crop produced. Four crops account for almost 97 percent of all crops produced. Winter wheat, spring wheat, barley and hay are by far the most important crops with durum wheat and oats being of limited importance. Rye, flaxseed, corn and sugar beets are of no economic consequence.

Crop yields definitely tend to fluctuate a great deal from year to year within all parts of the Study Area. This is due to a variety of factors, some of which are uncontrollable to management. One of the primary factors is, of course, the precipitation or rainfall received in the area. The total precipitation in any year is of major importance, but the timing of the receipt of that precipitation may be even more important.

Another important factor in terms of rainfall or precipitation is the carry-over soil moisture from one year to the other. A very critical time for many of the crops grown in the area is the availability of moisture in the late spring and early summer periods. It is possible to have a year when the precipitation is high on a yearly basis, and at the same time have very poor crop yields because of a severe lack of precipitation during a critical period within the growing season.

It is indeed, however, fair to say that crop yield is in large part a function of the precipitation and soil moisture conditions of the area. These are variables which are completely out of the control of management, yet are critical to the profitability and yield of crops in the area. Another important weather factor, of course, is the constant danger of wind and hail damage to crops of the area.

TABLE IV-2

1967 CROP ACREAGES HARVESTED & PASTURE

	Blaine		Chouteau		Glacier		Hill		Liberty	
	I	D	I	D	I	D	I	D	I	D
Winter Wheat	200	47,300	400	431,600	200	27,000	--	339,500	--	137,200
Spring Wheat	2,100	48,600	100	27,700	300	32,300	100	78,900	--	72,400
Durum Wheat	--	400	--	1,700	--	5,300	--	5,700	--	10,100
Barley	2,400	40,600	800	92,800	1,700	79,800	--	77,500	--	66,400
Oats	900	2,300	100	4,000	--	2,500	300	2,200	--	2,700
Rye	--	200	--	--	--	100	--	--	--	--
Flaxseed	--	500	--	200	--	200	--	200	--	--
All Hay	36,900	21,800	8,700	32,300	8,500	28,000	5,700	20,200	2,300	8,700
Corn Silage	900	100	100	200	--	--	600	200	--	--
Sugar Beets	930	--	--	--	--	--	--	--	--	--
TOTAL CROPLAND	44,330	161,800	10,200	590,500	10,700	175,200	6,700	524,400	2,300	297,500
Pasture		405,566		1,325,203		1,214,246		720,405		390,343

Source: Montana Agriculture Statistics - Montana Department of Agriculture & U. S. Department of Agriculture.

TABLE IV-2

1967 CROP ACREAGES HARVESTED & PASTURE CONT.

	Phillips		Pondera		Toole		Valley		Conservancy Dis.	
	I	D	I	D	I	D	I	D	I	D
Winter Wheat	--	22,100	2,500	126,300	--	77,300	200	14,300	3,500	1,222,600
Spring Wheat	800	76,900	800	27,000	--	101,700	3,200	240,000	7,400	705,500
Durum Wheat	--	1,400	300	20,900	--	10,000	300	5,900	600	61,400
Barley	900	24,300	4,100	75,400	--	102,800	1,500	56,500	11,400	616,100
Oats	1,200	3,300	700	2,000	--	2,300	500	3,300	3,700	24,600
Rye	--	100	--	--	--	900	--	100	--	1,400
Flaxseed	--	--	--	--	--	--	--	200	--	1,300
All Hay	33,700	39,800	14,200	15,700	1,800	12,700	22,000	37,200	133,800	215,900
Corn Silage	600	100	--	--	--	--	700	100	2,900	700
Sugar Beets	160	--	--	--	--	--	--	--	1,090	--
TOTAL CROPLAND	37,360	168,000	22,600	267,300	1,800	307,700	28,400	357,600	164,390	2,849,500
Pasture		1,925,168		357,820		503,208		1,651,603		8,493,562

Source: Montana Agriculture Statistics - Montana Department of Agriculture & U. S. Department of Agriculture

I - Irrigated land D - Dryland

Table IV-3 lists crop yields for the various crops, irrigated and dryland, for each county. Because of the great fluctuations in yield from year to year it is difficult to generalize. However, yields over the past ten year period substantiate the situation represented for 1967 in Table IV-3. Yields on wheat and barley appear to be consistently better in the western counties of Glacier, Pondera, Toole and Chouteau. The counties with the lowest yields have consistently been Blaine, Phillips and Valley in the eastern part of the district. Yields on the minor crops, although not very meaningful because of the small acreage harvested, are generally lower than in other areas of the state where production of those crops is more important. Hay yield is comparable to that in most parts of the state.

2. Livestock. As previously indicated, livestock production has become an increasingly important part of the area's economy over the past decade. Livestock production is concentrated in the three eastern most counties and in Glacier County. Livestock production accounts for more than or nearly half of all cash receipts to farms in those counties. (See Figure IV-2.) Even the major wheat producing counties have a significant income from livestock. Most of the livestock in the district are raised on farms which also rely in part on cash crops. The diversified farm is perhaps the most important to the area in terms of total cash receipts.

Table IV-4 indicates livestock numbers by county. Of major economic importance are cattle and sheep. The trend from 1957 to 1968 is toward more cattle and fewer sheep. In 1957 Blaine County produced more sheep that cattle, however, by 1968 cattle outnumbered sheep in Blaine County by almost three times. Hog production has increased over the past ten years, but is still relatively low. Milk cows and chickens are mostly raised for local farm needs and commercial operations are not of great economic importance primarily due to the lack of nearby markets.

TABLE IV-3

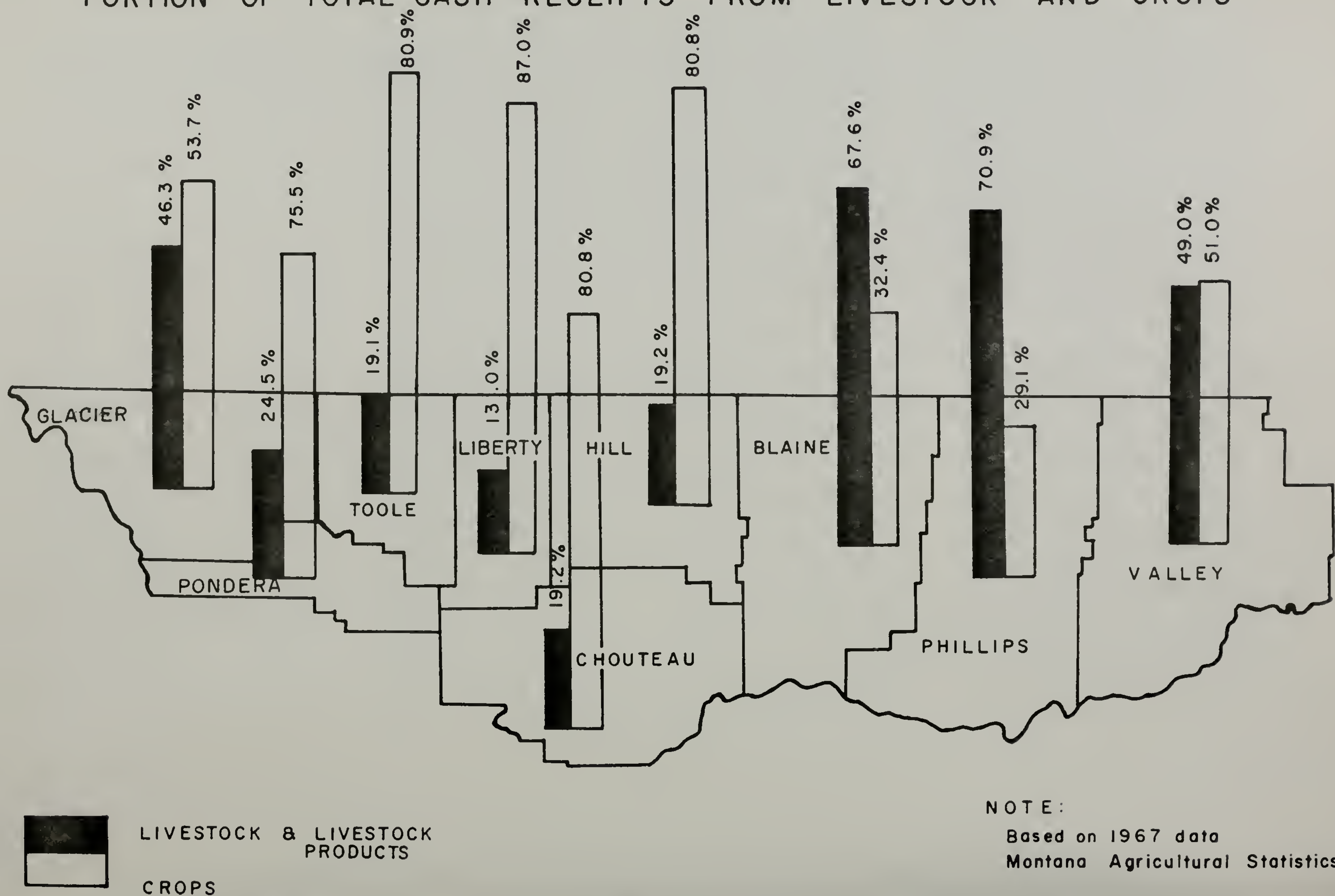
1967 CROP YIELDS* PER ACRE HARVESTED

	Blaine		Chouteau		Glacier		Hill		Liberty		Phillips		Pondera		Toole		Valley		Conservancy District	
	I	D	I	D	I	D	I	D	I	D	I	D	I	D	I	D	I	D	I	D
Winter Wheat	32	22	38	33	40	29	--	22	--	24	---	22	41	32	--	28	30	25	39	28
Spring Wheat	30	13	37	19	32	18	28	14	--	15	29	13	27	22	--	18	23	16	27	16
Durum Wheat	--	14	--	16	--	21	--	13	--	16	--	15	41	22	--	19	36	13	39	18
Barley	55	18	46	31	48	29	--	19	--	20	40	19	59	31	--	25	39	22	51	25
Oats	47	24	50	26	--	25	34	16	--	20	50	22	40	25	--	20	56	23	44	23
Rye	--	17	--	--	--	20	--	--	--	--	--	25	--	--	--	27	--	18	--	24
Flaxseed	--	6	--	9	--	10	--	6	--	--	--	--	--	--	--	--	--	5	--	7
All Hay	2.2	1.2	1.8	1.3	1.9	.9	2.0	.7	1.9	.9	1.9	.9	2.3	1.2	.9	1.8	2.5	.9	2.1	1.0
Corn Silage	16	5	14	6	--	--	12	4	--	--	20	4	--	--	--	--	16	5	16	5
Sugar Beets	14	--	--	--	--	--	--	--	--	--	13	--	--	--	--	--	--	--	--	14

Source: Montana Agriculture Statistics I - Irrigated land D - Dryland

FIGURE IV-2

PORTION OF TOTAL CASH RECEIPTS FROM LIVESTOCK AND CROPS



NOTE:
Based on 1967 data
Montana Agricultural Statistics

TABLE IV-4

Livestock On Farms & Ranches
January 1, 1957, 1963, 1968

	Blaine	Chouteau	Glacier	Hill	Liberty	Phillips	Pondera	Toole	Valley	Conservancy District
Cattle & Calves										
1957	67,700	55,300	38,400	30,300	14,200	78,100	19,400	18,300	67,300	389,000
1963	75,000	52,100	30,700	31,200	12,200	80,000	23,000	14,500	68,000	387,300
1968	91,000	70,000	45,000	37,000	14,000	98,000	35,000	23,000	92,000	508,000
Milk Cows										
1957	1,900	900	300	1,100	300	1,100	1,100	400	2,100	9,200
1963	1,700	700	300	900	200	900	800	300	1,200	7,000
1968	900	400	200	500	200	600	600	200	700	4,300
Hogs & Pigs										
1957	2,300	2,400	700	800	300	2,400	3,600	1,000	2,200	15,700
1963	5,000	5,100	1,700	1,700	1,100	4,200	6,200	1,000	3,100	29,100
1968	6,000	4,400	1,600	1,500	1,200	7,000	5,800	2,100	3,700	33,300
Sheep & Lambs										
1957	79,200	4,000	34,600	10,800	7,900	29,500	17,400	20,600	32,900	236,900
1963	45,900	5,300	23,100	3,800	3,100	24,100	15,100	11,500	28,200	160,100
1968	36,000	4,200	18,000	2,500	3,000	21,000	13,000	8,300	22,000	128,000
Chickens										
1957	37,100	38,700	7,200	23,400	10,500	24,200	27,500	14,900	43,900	227,500
1963	23,200	41,400	8,600	21,000	8,700	20,800	24,800	11,300	33,300	193,100
1968	25,000	35,000	21,000	25,000	10,000	20,000	21,000	10,000	37,000	204,000

Source: Montana Agriculture Statistics

3. Farm Numbers and Income. In 1945 the nine county area had approximately 7,500 farms.[4] By 1967 that number had declined to 5,696.[5] The trend is certain to continue as economic factors drive the small farmer out of business and the efficiencies of size encourage increasingly larger farming units. Table IV-5 lists farm numbers, size, value and receipts by county for 1967. Average farm size varies greatly from as high as 4,018 in Blaine County where most of the land is range and pasture to as low as 1,510 in Pondera County. Average farm values tend to be higher in the major wheat producing counties.

Marketing receipts per farm are the highest in Liberty County and the lowest in Valley County, averaging $22,200 for the district as a whole. Because those counties with the largest receipts per farm are also the grain growing counties, they receive a higher average government payment per farm than do the other counties.[6]

In conclusion, the agricultural economy of the North Central Conservancy District is by no means depressed, however, it does not have the kind of assured stability which is desirable. The trend toward more livestock production and away from predominant wheat production can contribute to such stability. However, major changes in the farming situation of the area could do much for a stable and growing economy. Irrigation may be a major alternative for the entire area.

4. The Effect of New Irrigated Acres to the Agricultural Economy. The introduction of irrigated lands into an agricultural economy such as the one previously described for the nine county area can indeed have varying kinds of effects. One of the most difficult of these effects to measure concerns the probable or likely effect of adding additional irrigated acres into the livestock economy of the area. In general, the associated cost-benefit ratios and the effect of changing irrigated acres from one cash crop to another are quite easily identified. However, benefits derived from shifting acres to irrigated crops to be used directly by livestock are much more difficult to quantify.

The probability is extremely high that a major portion of the new irrigated acres in the study area will go into crops which will be used directly in support of livestock. In fact, of the 164,390 irrigated acres within the boundaries of the Study Area, 151,800 acres (92.3 percent) are presently being used for the production of feed grains (oats and barley), corn silage and hay crops.[7] The benefits of raising crops to directly support the livestock enterprise can be identified on a cost basis of the crops to the livestock enterprise, but they are more accurately valued in terms of the end product - the livestock production itself. This is true because many of these crops are not

TABLE IV - 5
FARM NUMBERS, SIZE, VALUE & RECEIPTS IN 1967

	Blaine	Chouteau	Glacier	Hill	Liberty	Phillips	Pondera	Toole	Valley	Conservancy District
Number of Farms	631	945	413	792	322	634	623	430	906	5,696
Average Size of Farms (in acres)	4,018	2,691	3,938	2,325	3,004	3,662	1,510	2,795	2,651	2,876
Average Value per Farm	$121,000	$170,000	$174,000	$136,000	$184,000	$83,000	$150,000	$175,000	$103,000	$138,775
Average Value per Acre	$30	$63	$21	$58	$61	$23	$98	$62	$39	$46
Marketing Receipts per Farm	$20,912	$27,962	$19,366	$22,164	$31,189	$18,688	$20,226	$26,033	$17,455	$22,239
Government Payments per Farm	$2,120	$6,243	$2,332	$4,812	$5,822	$1,929	$4,381	$4,263	$3,618	$4,024
Total Cash Receipts per Farm	$23,032	$34,205	$21,698	$26,976	$37,011	$20,617	$24,607	$30,296	$21,073	$26,268

Source: Montana Agriculture Statistics

currently available for specific purchase within the area's market place.

An excellent example would be that irrigated pasture could be valued at a cost of three to four dollars per A. U. M. (animal unit month) and the benefits determined on the basis of the price of the A. U. M.'s of grazing produced. However, a more accurate method to evaluate the irrigated pasture would actually show the value of these A. U. M.'s by use of the pasture or A. U. M.'s produced within a given ranch situation as measured in livestock output. Such measurement is crucial to the analysis because of the growing importance of livestock production within the conservancy area -- accounting for 20.6 percent of all cash receipts in 1956 and 34.5 percent in 1967. Therefore, this section of the report proposes to clearly examine the benefits attributable to the new irrigated acres used directly in support of livestock production.

In an unpublished Ph. D. thesis completed in 1965 at Montana State University, Robert L. Sargent of the Department of Agricultural Economics describes alternatives for developing new irrigated lands on the Hardin unit which was developed as a result of the construction of the Yellowtail Dam.[8] The Hardin unit near Hardin, Montana, is approximately 140 miles south of the present Study Area. This thesis by Mr. Sargent contains a detailed section dealing with the likely enterprise combinations that would result if large acreages of irrigated land were developed under the Yellowtail Dam.

Mr. Sargent's analysis in his thesis examines the organization of individual, self-contained agricultural units entirely within the new irrigation unit. The conclusion that Mr. Sargent draws concerning enterprise combinations was that the irrigated land would be used in the following percentages for various kinds of groups of farm organizations:

Plan I	-	Cash crop	20%
Plan II	-	Cash crop, wintered feeder calf	20%
Plan III	-	Cash crop, beef cow, wintered calf	25%
Plan IV	-	Cash crop (no beets) beef cow and calf	10%
Plan V	-	Cash crop (no beets), summered feeder yearling	25%

These conclusions are supplemented by recent findings published by the Bureau of Indian Affairs in a study entitled "The Fort Peck Reservation Area -- Its Resources and Development Potential."[9] This B. I. A. study emphasizes that under "ideal" conditions at least 75 percent of the irrigated land would be used for livestock support crops, including feed base, pasture and hay.

The details included in this thesis allow one to estimate the approximate number of acreages which would be attributable directly to livestock production for each of the five plans contained above. For this analysis, it has been assumed that there are 5,000 new irrigated acres in the project. The following table shows the number of total acres attributable to each plan with the number of new irrigated acres devoted to livestock and cash crops for each of the five plans.

Plan	Percent of Total	Total Acres	Cash Crop	Livestock Acres
I	20%	1000	1000	0
II	20%	1000	430	570
III	25%	1250	275	975
IV	10%	500	50	450
V	25%	1250	125	1125
Total	100%	5000	1880	3120

It can thus be concluded from the material contained in the thesis by Mr. Sargent that nearly two-thirds of the new irrigated lands could be expected to go directly into the production of crops to support livestock production if the Yellowtail Dam project were to be successfully developed. It is interesting also to know, however, that Mr. Sargent's analysis examines self-contained units rather than existing units to which new irrigated land would be added within a given irrigation project. It would seem very likely that more than two-thirds of the land would go into the production of crops used in direct support of livestock production. One should examine the more realistic question for this study which is how will irrigated land be used when added on to existing agricultural units.

It is assumed that new irrigated lands in the Study Area would be added to existing dryland units rather than being farmed or operated as self-contained irrigated farms. If this is indeed the case, then one would certainly expect that a higher portion than was concluded by Mr. Sargent would go directly into the projection of crops for consumption by livestock. This is especially true when one examines the area and the growing importance of livestock production within the area at the present time.

The land is highly desirable for the production of livestock feed products and is less desirable for the production of cash crops relative to many other areas. Sugar beets would undoubtedly become an important cash crop to the area if large acres of irrigated land were developed and if one assumes that there would be a market for increased sugar beet production from these new irrigated lands. It is questionable that there would be a ready market for large increased acreages of sugar beets in the area because of the widely known fact that sugar beet production is restricted

at the present time in other areas of Montana such as the Yellowstone Valley, which has highly desirable land for sugar beet production. Additionally a desire exists within many of the irrigated farm units along the Yellowstone Valley for increased sugar beet production. It would certainly seem unlikely at the present time that large acreages of cash crop sugar beets would be produced on new irrigated land in the Study Area.

The first question which needs to be asked in this study is how are new potential irrigated lands likely to be used within the Study Area in terms of cash crops and livestock feeds? The answer to the question would definitely appear to be that a vast majority, if not nearly all of the increased irrigated lands, would be used directly in relationship to the production of livestock feeds recognizing that there will be some cash crops produced for a variety of reasons. The majority of the land would, however, probably be used for the support of livestock.

The next question, then, is to break down the use of the agricultural land or new irrigated acres between crops or feeds for livestock. This is indeed a much more complicated question, and the answer will be determined by the management of the individual operations within the Study Area. It is fair to say, however, that the new irrigated lands for the support of livestock would fall into three areas of livestock feed production. The first of these would be the production of winter feed which would be primarily related to the production of winter roughages such as alfalfa hay, corn silage and related silages and hay crops. Another important use of new irrigated land would be irrigated pasture to support livestock during spring and summer months and supplement dryland range during these periods. The third area of concern deals with the production of feed grains primarily barley and oats to support livestock during winter and possibly even summer periods. Most of this concentrate feed would probably be used in the support of growing livestock as a supplement to roughages.

The factor that will determine how the new irrigated lands are used will be the situations faced by the individual operations for which the irrigated lands would be available. The two critical factors which will determine this use will be the management factor as well as a clear identification as to resources which are available for use on these individual farm or ranch situations. An example is that one set of resources might dictate that the majority of additional acres go into the supply of winter feed because present resources do not allow one to produce sufficient winter feed to balance with other resources during other periods of the year. The opposite situation might exist, however, on another operation where winter feed can be produced in greater quantity than needed to supply the number of livestock which can be kept on the farm or ranch during summer periods.

Another important factor is that the addition of irrigated land to many operations allow one to plan for keeping calves for a longer period of time on the individual farm or ranch. An example is that because of the shortage of winter feed certain ranchers may often be forced to sell their calves at weaning time in the fall rather than having the option of keeping those calves through the winter and possibly the next summer before marketing them. This addition of irrigated acres would allow for more of this kind of flexibility on many of the agricultural units found within the Study Area.

An acquaintance with individual operations within the Study Area would certainly suggest that all of the above situations plus many others do exist at the present time and any specific quantifications of the number of acres which will go to various livestock feeds must be determined on the basis of these kinds of questions, and therefore, this study does not attempt to identify in a precise way the specific livestock feed crop which will be grown on additional irrigated land. It is also extremely difficult to determine the prices or exact impact of adding irrigated acres to individual farm units without fully understanding the present situation on those units.

It is certain, for example, that there is a considerable amount of straw which is available for winter feed in the area as a low quality roughage that is not presently utilized. Part of the reason for this poor utilization of low quality roughage may well be tied to the lack of other concentrate and high quality roughage which can be fed in combination with straw. An example would be that producing large quantities of top quality alfalfa hay would allow not only the wintering of more livestock, but also more effective utilization of low quality roughage such as wheat and barley straw which are bi-products of cash crops and/or feed crops now grown in the area.

Thus, it becomes clear that the addition of an acre of alfalfa hay yielding three tons per acre would be of more benefit to the individual farm unit than just the A. U. M. 's of feed provided by the hay itself. It could be assumed that approximately six hundred pounds of alfalfa hay would comprise an A. U. M. of winter feed and thus three tons of alfalfa hay would be the equivalent of approximately ten A. U. M. 's of winter feed. The importance of this alfalfa hay could be more than just the ten A. U. M. 's, however, because the availability of alfalfa might allow for a better utilization of the low quality roughages such as straw which are in surplus or in abundance on many units. This would not always be the case, but in many situations it certainly would be reasonable to assume that this would be the situation.

An example similar to the one discussed above in relationship to the providing of irrigated pasture as a summer feed also exists. The range science technology available certainly dictates that the most detrimental time to graze dryland range is during the early spring and mid-summer periods when the range crops are growing and struggling to maintain themselves on the range. It is, therefore, considered beneficial to existing dryland range resources if grazing can be deferred during the early spring

and mid-summer period to allow for a steady, undistrubed growth of the range plants. Such practices are in most instances not possible under present conditions. However, if one had large acreages of irrigated pasture to use during this early spring and mid-summer grazing period, it would then be possible to use the dryland range resources during the late summer and fall period to supply feed for livestock. This late fall and early winter use of pasture would in some instances result in substituting A. U. M. 's of grazing from range for winter feed such as hay or silage. Thus, it is again obvious that in certain situations one acre of irrigated pasture would yield a benefit to the individual farm or ranch situation of more than just the value of the 8 to 12 A. U. M. 's of feed produced. This could be done by allowing better utilization of all resources while continually improving the dryland range resources by putting it to a more desirable use.

The production of feed grain on irrigated acres may also allow for considerably more value in terms of managing livestock than is reflected by the value of the grain itself. For example, the availability of high quality feed grain produced on irrigated acres would allow one home grown supplement concentrate feeds for not only the wintering of breeding stock but also the wintering and/or growing out of calves. These feed grains could be used in a variety of ways depending upon the individual situation as supplement in either growing of feeder calves for rapid gain during either summer or winter periods by supplementing roughage with feed grains. It is also conceivable that there could be certain quantities of feed grain which would go directly into the feeding of livestock on individual farms or ranches. There is indeed considerable interest in additional cattle feeding within Montana and certain situations might dictate that large acreages of feed grains would be produced on irrigated lands to support livestock feeding operations within the area where the feed barley would be either sold as a cash crop or flow directly into feeding operations on individual farm units.

Another benefit to the inclusion of more irrigated acres to supply livestock feeds centers around the fact that a low utilization of labor during certain periods of the year continues to be a problem for many farm units within Montana.[10]

Many farm units find that they have an excess of labor which is unemployed during certain periods of the year because the farm does not require the quantity of labor that is available on the farm as basically a fixed resource as family labor. The addition of livestock to such organizations would allow for a better and more uniform utilization of family labor over a total year's time. This fact was pointed out by Robert Sargent in his thesis referred to above and also stressed or identified as an important problem to the agriculture of Montana in the upper Midwest Economic Study paper number 3.[11] It is, therefore, entirely possible that the addition of irrigated lands to certain operations within the study area would not only allow the operation to have increased agricultural output but also allow them to better utilize family labor.

The conclusion is, thus, that the addition of irrigated acres for the production of livestock feed in the form of either winter feed, summer feed or supplement feed allow for the possibility that there are significant benefits to the individual farm or ranch over and above the actual feed production itself.

The fact that the addition of irrigated lands adds more stability to the individual farm or ranch situation may well allow the individual farm or ranch situation to better utilize all resources within the given range. Examples have been pointed out above as to better utilization of straw, better utilization of dryland range and/or more flexibility in livestock management.

In order to quantify these effects one has to understand and know the individual farm or ranch situation into which the new irrigated land would be introduced. Nevertheless, these factors should be recognized as possible benefits which would be attributable to adding irrigated acres within individual situations fully recognizing that the only way to quantify them in exact terms is to do detailed research not warranted in this preliminary feasibility study. These factors are recognized, and there would undoubtedly be such benefits in addition to the feed production itself by adding irrigated acres for livestock production.

Present agricultural practices in the Study Area will need to be partially adapted to irrigation farming with alfalfa hay, corn silage, irrigated pastures and cattle. The adjustment to irrigated agriculture will in many cases require substantially increased individual farm investments for land leveling, farm laterals, fences, farmstead buildings and seeding of hay and pastures. Two major requirements for successful development of the area will be access to sufficient capital and efficient management of the resources.

Even though the irrigation of such lands represents a substantial investment, the resulting additional production would be larger and more dependable than previous dryland operations. The amount of increased income that can be expected from an area after irrigation has been fully developed may be shown by comparing the usual dryland returns to the returns from the same area after about 15 years of irrigation. Such estimates have been made by the Bureau of Reclamation for the Hardin unit,[12] and it is anticipated that these results would also be quite representative of the effects of irrigation within the Study Area.

Within the 83,900 acre Hardin unit, the Bureau of Reclamation has identified 52,900 acres used for dryland wheat and barley and about 31,000 acres of grazing land.[11] Based on average yields and prices the area would produce a gross annual return of nearly one million dollars -- the equivalent of $12.00 per acre including crops, fallow and range land. According to Bureau calculations, the gross return from irrigated farming of 42,600 acres integrated with the present non-irrigable portion

would increase to nearly four times that realized without irrigation. Despite increasing total farm costs from more intensive operations, the net return to labor and management could also be expected to increase nearly four times.[14]

C. ECONOMIC IMPACT OF WATER RESOURCES DEVELOPMENT

Any attempt at predicting the economic impact of supplying water for the irrigation of new lands in the Study Area results in some rather startling conclusions. Numerous detailed studies have been made by Universities and governmental agencies on the history and experience of other irrigation projects in the Northern Great Plains. Many findings from these studies are mentioned briefly in this section and throughout this report. For those interested in more detail, a number of references on the social, economic, and political factors associated with the development of water resource projects is given in the Bibliography.

The indirect benefits which can result from the introduction of irrigation into an area are many. Quantitative predictions of such benefits are in some cases impossible due to the non-quantifiable nature of the benefit and in other cases tenuous at best. However, it is important to recognize these potential non-agricultural benefits and the costs which are likely to accompany them.

Of primary importance is the general stabilization of the economy which irrigation can produce. As was previously discussed, dryland farming has the drawback of being largely dependent on precipitation and other weather conditions. Irrigation removes the uncertainty related to an adequate water supply and results in a stabilization of farm income. A stabilized farm income allows the business community in the area to function with more long range objectives in terms of growth and development. Specifically, banks in the area can look to expanded deposits and less risk in their lending operations. An examination of the small rural banks in dryland farming areas reveals that deposits do not increase at a stable rate and in fact, decrease during some years. The problem is complicated by the fact that the demand for loans (particularly consumer loan) is greatest during those years when farm income is low due to poor crop yield. These are the same years when deposits are likely to be low, a situation which makes the banking business extremely uncertain.

The general business community will also benefit from a stabilized agricultural economy. Retail businesses are able to carry larger and expanded inventories. The corresponding benefit to wholesalers is similar with a high degree of certainty with respect to anticipated future business, businesses are more able to plan their future development.

Irrigation which leads to increased crop yields and expanded livestock production will also lead to increased incomes and increased land values. For every dollar added to agricultural income in the area, there will be a multiplier effect in the other sectors of the economy. Although the prediction of that multiplier effect is difficult, estimates made for other similar areas have been surprisingly consistent. A study of the Montana economy estimates that for each dollar generated in the agricultural crops sector there is a total of $2.83 generated in the entire state economy.[15] A seven county North Dakota study estimated a gross receipts multiplier of $3.02.[16] A study in East-Central Wyoming put the multiplier at $2.97.[17] Whatever the real multiplier effect is, it is certain that increased agricultural income will have a significant impact on the rest of the economy.

A further result of stabilized and increased income will be a stabilization or increase in total population. New farm families will move into the area, and the rate of out-migration will be greatly reduced. Although farm numbers are likely to continue to decline, that rate of decrease will be greatly reduced. Correspondingly, farm sizes will increase at a decreasing rate. Farm employment should become more stable and less seasonal as a result of increased livestock production and a generally more intensive agriculture.

In addition, non-agricultural employment can be significantly expanded. A Colorado study has concluded that "one hundred farmers and hired farm workers may stimulate employment for anywhere from 170-240 non-farm workers. One hundred dollars of income earned by farmers and hired farm workers may be associated with a range of $200 and $270 of income for workers in the linked and derivative sectors of the local economy".[18]

Another major impact of the introduction of irrigation will be benefits and costs related to government and public services. As incomes increase and land values increase, the tax base of the area will be significantly expanded. The tax base will also be improved as a result of physical improvements and machinery which will accompany an irrigated agriculture.

The cost related to this expanded tax base will be the need for expanded public services. An increased population will require more schools, hospitals, roads, etc. However, such expansion in most cases will lead to improved facilities of benefit to the area.

Finally, a significant benefit which can accrue to the area is a more organized and cohesive community leadership. As the area becomes more interrelated and integrated due to the irrigation system, the leadership and organization can be applied to the many other improvements required in the area. This organization and leadership can do

much to provide direction and impetus to the future development of the area.

FOOTNOTES - PART IV

[1] County and City Data Book, 1967, Bureau of the Census, U. S. Dept. of Commerce, pp. 223, 226.

[2] County and City Data Book, 1967, Bureau of the Census, U. S. Dept. of Commerce, pp. 220, 221, 230, 231.

[3] The preceding two paragraphs based on Montana Agricultural Statistics, December 1958 and December 1968.

[4] Computed from data on p. 79, Montana Agricultural Statistics, December 1946.

[5] Computed from data in Table; Cash Receipts by County-1967, p. 17, Montana Agricultural Statistics, December 1968.

[6] See Table IV-5.

[7] Computed from table IV-3 which is based on Montana Agricultural Statistics, December 1968.

[8] See reference IV-3.

[9] See reference IV-9.

[10] Observation of Lloyd C. Rixe based upon individual field and research experience.

[11] Borchert, John R. and Russel B. Adams, Trade Centers and Trade Areas of the Upper Midwest, Urban Report Number 3, Upper Economic Study, September 1963.

[12] See reference IV-5.

[13] See reference IV-6.

[14] Observation of Lloyd C. Rixe based upon individual field and research experience.

[15] See reference IV-4.

[16] See reference IV-7.

[17] See reference IV-8.

[18] See reference IV-9.

PART V

WATER SUPPLY REQUIREMENTS

PART V

WATER SUPPLY REQUIREMENTS

A. MUNICIPAL AND RURAL WATER REQUIREMENTS

1. The Table entitled "Municipal Inventory" shows water supply source and waste water facility for each town and community in the Study Area.[1] The information for this table was taken from the "Comprehensive Area Water and Sewer Plan" for each county as prepared by Mueller Engineering and Theodore J. Wirth and Associates.[2]

Population for 1970 was obtained from the recent census where they were available and are also shown in the Municipal Inventory. As pointed out earlier, the total population within the nine county area has decreased from the 1960 census of 86, 945 to the present population of 73, 007. Historic population trends indicate a relatively unstable population since 1930. Hopefully, the economy of the area will stabilize and the population-decline trend will turn upward to show a population increase over the period of study. It is estimated that the population in the area will reach 86, 000 by the year 2020.[3] In 1970, the municipal population of the area was approximately 62% of the total area population. It is estimated that approximately 75% of the total population will be living in the municipalities by 2020.[4] The municipal population projections for the year 2020 are shown in the inventory.

There are a total of sixty-five towns and communities located in the Study Area. The domestic and industrial water requirements are satisfied by surface water in 21 communities and by groundwater in 44 communities. With the exception of Shelby, Malta and Glasgow, the largest population center in each County of the Study Area is served by a surface water supply. Shelby has a well supply on the Marias River while Malta and Glasgow have wells in the Ancient Missouri River channel.

Twenty-four of the communities have adequate water supplies. Twenty-nine of the communities need a new supply source, while the remaining 12 communities need to expand upon their existing water source.

2. Water Quality. Water quality data from the municipal water supply is primarily determined by routine sampling by the Montana State Health Department.[5] Table V-2 is an excerpt from their records.

The recommended maximum limits for drinking water standards are as follows:[6]

Numbers refer to footnotes located at the end of this chapter.

MUNICIPAL INVENTORY

COUNTY	MUNICIPALITY	ESTIMATED POPULATION 1970 *	2020	WATER SUPPLY SOURCE EXISTING	NEEDS IMPROVEMENTS	WASTE WATER FACILITY EXISTING	PROPOSED
	CUT BANK	4,004	4,975	CUT BANK CREEK	TREAT PLANT EXPANSION	PONDS	PONDS
	BROWNING	1,700	3,075	SPRINGS - 6 MIN. W.	ADDITIONAL SUPPLY	PONDS	PONDS
	EAST GLACIER	369	500	MIDVALE CREEK	ADEQUATE	SEPTIC TK.	PONDS
GLACIER	SANTA RITA	112	200	PRIVATE WELLS	SUPPLY FROM CUT BANK	SEPTIC TK.	PONDS
	BABB	51	70	SPRING AND PRIVATE WELLS	NEW WELL & SYSTEM	SEPTIC TK.	SEPTIC TK.
	ST. MARY	31	50	PRIVATE WELLS	NEW WELL & SYSTEM	SEPTIC TK.	SEPTIC TK.
	BLACK FOOT	36	40	PRIVATE WELLS	ADEQUATE	SEPTIC TK.	SEPTIC TK.
	SHELBY	3,111	4,640	6-WELLS MARIAS R. 7 MI. S.	NEW WELL	PONDS	PONDS
	SUNBURST	604	825	4-WELLS - 15 MI. W.	ADEQUATE	SEPTIC TK.	PONDS
	KEVIN	250	460	WELLS & SPRINGS - 10 MI. W.	NEW WELL	PONDS	PONDS
TOOLE	SWEETGRASS	202	200	MILK RIVER - COUTTS, CANADA	ADEQUATE	SEPTIC TK.	PONDS
	OILMONT	89	80	HAUL WATER - KEVIN, SHELBY	NEW SUPPLY	SEPTIC TK.	PONDS
	GALATA	40	30	HAUL WATER - SPRING 7 MI. N.	NEW SUPPLY	SEPTIC TK.	SEPTIC TK.
	DEVON	36	30	HAUL WATER - SHELBY	NEW SUPPLY	SEPTIC TK.	SEPTIC TK.
	ETHRIDGE	30	30	HAUL WATER - SHELBY	NEW SUPPLY	SEPTIC TK.	SEPTIC TK.
	CHESTER	936	1,500	TIBER RES. - 14 MI. S.	ADEQUATE	PONDS	PONDS
LIBERTY	JOPLIN	31	275	FRESNO RES. HILINE WATER CO.	ADEQUATE	PONDS	PONDS
	LOTHAIR		30	HAUL WATER - SPRING NW.	NEW SUPPLY	SEPTIC TK.	SEPTIC TK.
	HAVRE	10,558	18,000	MILK RIVER	ADDITIONAL SUPPLY	PRI TREAT	SEC. TREAT
	RUDYARD	509	260	FRESNO RES. HILINE WATER CO.	ADEQUATE	PONDS	PONDS
HILL	GILDFORD	288	260	FRESNO RES. HILINE WATER CO.	ADEQUATE	SEPTIC TK.	PONDS
	HINGHAM	262	250	FRESNO RES. HILINE WATER CO.	ADEQUATE	PONDS	PONDS
	INVERNESS	167	160	FRESNO RES. HILINE WATER CO.	ADEQUATE	SEPTIC TK.	PONDS
	KREMLIN	178	150	FRESNO RES. HILINE WATER CO.	ADEQUATE	SEPTIC TK.	PONDS
	BOX ELDER	252	310	PRIVATE WELLS	NEW WELL & SYSTEM	PONDS	PONDS
	ROCKY BOY	178	280	WELLS & PRIVATE WELLS	NEW WELL & SYSTEM	PONDS	PONDS
	CHINOOK	1,813	2,590	MILK RIVER	TREAT PLANT EXPANSION	SEC. TREAT.	SEC. TREAT.
	HARLEM	1,094	1,455	MILK RIVER	ADEQUATE	SEC. TREAT.	SEC. TREAT
	HAYS	563	650	PRIVATE WELLS	NEW WELL & SYSTEM	SEPTIC TK.	PONDS
BLAINE	TURNER	162	180	PRIVATE WELLS	NEW WELL & SYSTEM	SEPTIC TK.	PONDS
	HOGELAND	67	65	PRIVATE WELLS	NEW WELL & SYSTEM	SEPTIC TK.	PONDS
	ZURICH	85	80	PRIVATE WELLS	NEW SURFACE SUPPLY	SEPTIC TK.	PONDS
	LODGEPOLE	54	60	PRIVATE WELLS	NEW SUPPLY	SEPTIC TK.	SEPTIC TK.
	MALTA	2,195	2,690	3 - WELLS	ADEQUATE	PONDS	PONDS
	SACO	356	300	2 - WELLS	NEW WELL	PONDS	PONDS
	DODSON	196	295	WELL	ADEQUATE	PONDS	PONDS
PHILLIPS	ZORTMAN	135	140	HAUL WATER - SPRING	NEW SURFACE SUPPLY	SEPTIC TK.	PONDS
	LANDUSKY	85	80	PRIVATE WELLS	NEW WELL & SYSTEM	CESSPOOL	PONDS
	LORING	40	45	PRIVATE WELLS	NEW WELL & SYSTEM	SEPTIC TK.	PONDS
	WHITEWATER	85	85	PRIVATE WELLS	NEW WELL & SYSTEM	SEPTIC TK.	PONDS
	WAGNER	40	45	PRIVATE WELLS	NEW WELL & SYSTEM	SEPTIC TK.	PONDS

* DENOTE OFFICIAL 1970 CENSUS OF POPULATION FOR ALL INCORPORATED PLACES AND UNINCORPORATED PLACES OF 1000 OR MORE.

TABLE V-I

MUNICIPAL INVENTORY

COUNTY	MUNICIPALITY	ESTIMATED POPULATION 1970 *	2020	WATER SUPPLY SOURCE EXISTING	NEEDS IMPROVEMENTS	WASTE WATER FACILITY EXISTING	PROPOSED
	GLASGOW	4,700	8,000	3 - WELLS	ADEQUATE	PONDS	PONDS
	NASHUA	513	640	WELL	NEW SURFACE SUPPLY	PONDS	PONDS
	OPHEIM	306	345	2 - WELLS	ADEQUATE	PONDS	PONDS
	FRAZER	369	350	2 - WELLS	NEW WELL	PONDS	PONDS
VALLEY	TAMPICO	31	35	PRIVATE WELLS	ADEQUATE	SEPTIC TK.	SEPTIC TK.
	HINSDALE	333	320	WELL	ADEQUATE	SEPTIC TK.	PONDS
	OSWEGO	54	60	PRIVATE WELLS	NEW WELL	SEPTIC TK.	PONDS
	RICHLAND	41	25	PRIVATE WELLS	ADEQUATE	SEPTIC TK.	SEPTIC TK.
	GLENTANA	47	45	PRIVATE WELLS	ADEQUATE	SEPTIC TK.	PONDS
	VANDALIA	16	10	PRIVATE WELLS	ADEQUATE	SEPTIC TK.	SEPTIC TK.
	CONRAD	2,770	3,625	LAKE FRANCIS	TREAT. PLANT EXPANSION	PONDS	PONDS
	VALIER	651	675	3 - WELLS	NEW SURFACE SUPPLY	PONDS	PONDS
PONDERA	BRADY	202	215	IRRIGATION DITCH & RES.	NEW TREAT. PLANT	PONDS	PONDS
	DUPUYER	108	100	PRIVATE WELLS	NEW WELL & SYSTEM	SEPTIC TK.	PONDS
	HEART BUTTE	157	175	HAUL & PRIVATE WELLS	NEW WELL & SYSTEM	SEPTIC TK.	PONDS
	LEDGER	15	15	HAUL - CONRAD	NEW SUPPLY	SEPTIC TK.	SEPTIC TK.
	FORT BENTON	1,863	2,485	MISSOURI RIVER	TREAT. PLANT EXPANSION	PONDS	PONDS
	BIG SANDY	827	1,300	15 - WELLS	NEW SUPPLY	PONDS	PONDS
	GERALDINE	370	325	3 - WELLS	ADEQUATE	PONDS	PONDS
	HIGHWOOD	178	175	3 - WELLS	ADEQUATE	SEPTIC TK.	PONDS
CHOUTEAU	CARTER	135	140	HAUL WATER TETON R. WELL	NEW 5 MI. SUPPLY LINE	SEPTIC TK.	PONDS
	LOMA	135	140	PRIVATE WELLS	NEW SUPPLY & SYSTEM	SEPTIC TK.	PONDS
	SQUARE BUTTE	67	40	2 - SPRINGS 3 MI. SW	ADEQUATE	SEPTIC TK.	SEPTIC TK.
	FLOWEREE	40	35	HAUL WATER	NEW SURFACE SUPPLY	SEPTIC TK.	SEPTIC TK.

* DENOTE OFFICIAL 1970 CENSUS OF POPULATION FOR ALL INCORPORATED PLACES AND UNINCORPORATED PLACES OF 1000 OR MORE.

SOURCE: REFERENCES V-1 through V-9

TABLE V-1 CONT.

MONTANA STATE DEPARTMENT OF HEALTH

DIVISION OF ENVIRONMENTAL SANITATION

CHEMICAL ANALYSIS OF MUNICIPAL WATER SUPPLIES
(All Figures in Milligrams per Liter)

CITY OR TOWN	SOURCE	DATE	TOTAL SOLIDS	HARD-NESS	CA	MG	NA K	CO_3	HCO_3	SO_4	CI	NO_3	F	FE	AS	PB	CU	ZN
BIG SANDY	Well near town	3/70	1120	195	50	16	390	0	520	475	20	105	0.6	0.35	0.008	0.0	0.0	-
	Water Tank well	3/70	2750	195	46	20	920	0	995	1080	170	6	3.5	1.52	0.002	0.0	0.0	-
	Field well	3/70	440	195	46	20	102	0	375	95	5	5	0.6	0.25	0.01	0.0	0.0	-
	Well near creek	3/70	390	185	46	17	96	0	360	75	8	8	0.5	0.05	0.009	0.0	0.0	-
	Collection well Infiltration system Old well	3/70	360	230	68	15	48	0	323	55	8	1	0.4	0.05	0.002	0.008	0.0	-
BRADY	Irrigation Ditch	8/67	1080	568	66	98	134	12	293	521	29	2	0.82	0.0	0.002	-	-	-
BROWNING	Springs	8/66	200	143	26	19	35	6	214	26	5	0.7	0.0	0.00	0.00	0.01	0.00	-
CHESTER	Tiber Reservoir	7/61	360	230	51	25	24	6	146	144	0	0.4	0.4	0.1	-	-	-	-
	Well #1 under Tank	7/61	2370	30	3	5	846	30	525	1247	58	2.2	1.0	0.4	-	-	-	-
	Well #2 by Tip Top	7/61	2045	40	5	7	725	18	512	1035	62	1.1	0.9	3.3	-	-	-	-
CHINOOK	Milk River	12/67	336	170	28	24	54	12	153	107	20	0.2	0.48	0.1	0.001	-	0.00	-
CONRAD	Lake Francis	8/67	194	145	27	19	26	18	152	31	9	0	0.18	0.3	0.001	-	-	-
CUT BANK (City)	Cut Bank Creek	8/64	370	224	51	24	44	0	201	133	9	0.0	0.0	0.00	0.00	0.00	0.00	-
	Northside Well	8/68	3790	560	132	54	1013	0	628	2030	80	0	1.4	0.04	-	-	-	-
CUT BANK (Union 76)	Pasture Well	8/67	1130	365	66	49	280	0	549	487	9	0.0	0.6	0.07	0.00	0.00	0.00	0.00
	Corrigoux #2	8/67	1280	140	26	18	440	0	625	429	57	0.0	0.8	0.00	0.00	0.00	0.00	0.00
	Corrigoux #3	8/67	1296	170	24	27	431	0	573	533	57	0.0	0.17	0.10	0.00	0.00	0.00	0.00
DODSON	Well	3/63	825	340	95	25	145	0	375	315	9	2.3	0.1	0.0	-	-	-	-
EAST GLACIER	Midvale Creek	8/65	54	45	14	3	13	0	73	9	5	0.0	0.0	0.94	0.00	0.02	0.00	-
FLAXVILLE	Well #1	11/66	780	512	60	88	62	0	366	95	66	186.0	0.2	0.25	-	0.00	0.00	-
	Well #2	10/67	1270	695	86	117	397	24	201	172	140	196.0	0.22	0.0	0.002	-	-	-
FORT BENTON	Missouri River	2/68	274	175	44	16	30	0	189	68	10	1.2	0.80	1.02	0.014	0.00	0.58	0.04
FORT PECK	Fort Peck Reservoir	10/67	420	243	57	26	50	0	201	165	11	3.0	1.18	0.5	-	-	-	-
GERALDINE	Well #1	10/68	564	640	76	110	0	0	324	194	17	0.2	6.1	0.5	0.0	0.008	0.00	-
	Well #2	12/68	538	270	60	29	92	0	324	167	18	0	6.1	0.1	0.0	0.004	0.0	-
	Well #3	10/68	538	420	52	71	21	0	336	128	40	0.2	6.4	0.7	0.0	0.0	0.0	-
GLASGOW	Well #1	8/65	1008	405	96	40	218	0	490	329	92	0.0	0.7	1.60	-	-	-	-
	Well #2	8/65	1278	430	110	50	304	0	530	302	275	0.0	0.8	2.34	-	-	-	-
	Well 3	8/65	1150	395	94	39	292	0	488	344	195	0.0	0.9	1.60	-	-	-	-
HARLEM	MILK RIVER	12/69	430	250	44	34	74	0	268	147	25	0	0.4	0.08	0.0025	0.00	0.05	0.05
HAVRE	Well #1	8/65	960	405	84	48	195	0	503	330	35	27.6	0.7	0.00	0.00	0.00	0.00	-
	Well #3	8/65	1370	385	88	40	345	0	555	585	44	0.0	1.1	0.00	0.00	0.00	0.00	-
	Well #4	8/65	656	255	60	26	140	0	342	240	22	0.0	0.6	0.00	0.00	0.00	0.00	-
	Milk River Composite	8/2/65-8/16/65	288	140	36	12	59	0	195	90	8	0.0	0.2	0.00	0.00	0.00	0.00	-
HIGHWOOD	Well	4/66	274	193	51	16	32	0	214	78	3	0.0	0.3	0.00	0.00	0.012	0.00	0.00
HILL COUNTY WATER DISTRICT	Fresno Dam	12/67	278	185	40	21	35	0	207	71	10	0.4	0.4	0.0	0.0	0.002	-	-

MONTANA STATE DEPARTMENT OF HEALTH

DIVISION OF ENVIRONMENTAL SANITATION

CHEMICAL ANALYSIS OF MUNICIPAL WATER SUPPLIES
(All Figures in Milligrams per Liter)

CITY OR TOWN	SOURCE	DATE	TOTAL SOLIDS	HARD-NESS	CA	MG	NA K	CO_3	HCO_3	SO_4	Cl	NO_3	F	FE	AS	PB	CU	ZN
HINSDALE	Well	8/65	1628	685	150	76	285	0	567	752	39	2.0	0.9	0.00	-	-	-	-
KEVIN	Spring #1	8/67	570	306	66	34	71	0	253	219	10	6	0.6	0.0	0.0	-	-	-
	Spring #2	8/67	422	228	31	12	97	12	134	187	8	1.2	0.16	0.0	0.0	-	-	-
	Big West Well	8/68	460	155	25	22	123	30	226	166	7	0	0.26	0.0	0.0	-	-	-
	Well #1	8/67	572	107	27	10	171	30	384	98	9	0	0.74	0.0	0.002	-	-	-
	Well #2	8/57	525	109	26	11	179	0	418	142	5	0	0.4	0.0	-	-	-	-
	Well #3	8/57	725	75	16	9	283	0	607	170	11	0	1.4	0.0	-	-	-	-
	Well #4																	
	Well #5																	
	Well #6																	
	Well #7																	
	Well #8	8/67	370	199	29.	30	46	6	140	142	8	2	0.2	0.0	0.003	-	-	-
	Well #9	8/64	535	337	88	29	50	0	275	202	5	11.0	0.1	3.6	0.00	0.00	0.10	-
MALTA	Well #1	6/67	860	311	72	32	199	0	415	358	19	2.5	0.7	0.00	-	-	-	-
	Well #2	6/67	870	306	74	30	204	0	421	359	21	1.2	0.7	0.00	-	-	-	-
	Well #3	9/69	1272	450	68	68	225	0	445	500	34	0	0.58	0.10	-	-	-	-
	Well #4	9/69	808	440	48	78	96	0	397	278	22	0	0.60	0.10	-	-	-	-
NASHUA	Well	9/65	2284	780	194	72	452	0	534	1218	34	0.0	1.2	0.24	-	-	-	-
OPHEIM	Well #1 (Old)	7/63	238	114	13	20	50	42	180	14	6	5.1	1.4	0.12	0.0	0.0	0.0	-
	Well #2 (New)	7/63	376	16	6	0	145	48	269	24	4	0.0	1.3	0.16	0.0	0.0	0.0	-
SACO	Town Well	7/63	3082	748	123	107	685	0	183	1760	175	1.6	0.8	0.24	0.0	0.0	0.0	-
	Schelle Well	7/63	394	100	13	16	120	12	165	171	17	0.0	0.3	0.10	0.0	0.0	0.0	-
SHELBY	Well #1	8/66	364	193	33	11	88	6	177	146	8	0.0	0.3	0.10	0.00	0.01	0.00	-
	Well #2	8/66	414	204	42	24	72	6	183	177	9	0.0	0.3	0.15	0.00	0.00	0.00	-
	Well #3	8/66	380	198	42	23	59	0	198	148	7	0.0	0.3	4.08	0.00	0.00	0.00	-
	Well #4	8/66	390	220	38	31	64	0	217	160	9	0.0	0.3	1.66	0.06	0.00	0.00	-
	Well #5	8/66	324	165	33	20	60	0	189	122	8	0.0	0.3	1.44	0.00	0.00	0.00	-
SQUARE BUTTE	Springs	4/66	366	121	33	9	105	0	354	47	6	0.0	0.8	0.00	0.00	0.00	0.00	-
SUNBURST	Well #1	4/64	1335	352	92	30	360	0	500	698	12	0.0	0.3	0.00	0.00	0.45	0.00	-
	Well #15	8/67	1020	39	11	3	384	24	653	257	23	0.0	1.06	0.0	0.001	-	-	-
SWEETGRASS	Coutts, Alberta, Canada	7/69	160	150	28	20	4	0	158	15	10	0.6	0.18	0.0	0.001	0.0	0.04	0.0
	Milk River	8/67	126	109	29	9	12	12	122	9	4	0	0	0	-	-	-	-
VALIER	Well #1	7/69	626	390	52	63	74	0	378	207	18	2.1	0.54	0.00	0.000	0.00	0.00	0.00
	Well #2	7/69	632	380	64	54	87	0	396	188	19	3.6	0.50	0.00	0.00	0.00	0.00	0.00
	Well #3	7/69	574	340	48	54	91	0	353	194	19	2	0.42	0.00	0.00	0.00	0.00	0.00

CA	CALCIUM	NO_3	NITRATE
MG	MAGNESIUM	F	FLORINE
NA,K	SODIUM & POTASSIUM	FE	IRON
CO_3	CARBONATE	AS	ARSENIC
HCO_3	BICARBONATE	PB	LED
SO_4	SULFATE	CU	COPPER
Cl	CHLORIDE	ZN	ZINC

TABLE V-2 (CONT)

Total Dissolved Solids	500
Sulfate (SO_4)	250
Chloride (CL)	250
Nitrate (NO_3)	45
Flourine (F)	1.7
Iron (FE)	0.3
Arsenic (AS)	0.01
Lead (PB)	0.05
Copper (CU)	1.0
Zinc (Zn)	5.0

Generally speaking, the groundwater in the area contains too much dissolved mineral matter. Water with more than 1,000 PPM dissolved solids usually contains minerals which give a disagreeable taste. Groundwaters contain considerable quantities of sodium carbonate or sodium bicarbonate and are alkaline.

Other groundwaters contain high amounts of magnesium sulfate (Epsom salt) and sodium sulfate (Glauber's salt) which impart a bitter taste to the water and may act as a laxative for people not accustomed to drinking it. Iron in water causes staining of plumbing fixtures and clothes and incrustation of piping.

There is very little data available regarding the quality of raw surface water. The best source of information is the Bureau of Reclamation Study that was made in connection with the Marias Milk Unit.[7] Daily water samples were collected from the Marias River near Chester and from the Milk River near Havre for the period 1965 to 1967. The results of this sampling program are shown in Table V-3.

Table V-3

Item	Marias River Chester	Milk River Havre
Sodium absorption ratio	1.0	1.4
Total dissolved salts (ppm	411.0	278.0
Boron (ppm)	.05	.07
Sulfates (ppm)	172.0	66.0
Chlorides (ppm)	3.8	3.6

These records demonstrate the general good quality of the water for irrigation.[8] Salt concentrations are relatively low even during periods of low runoff. Treated municipal water quality data from surface water sources is available in the following discussions.

In 1965 Congress passed the Federal Water Quality Act which required that all states classify and establish water quality criteria for their interstate streams. Following a public hearing in Helena during May 1967, revised classifications and water quality criteria were adopted for both interstate and intrastate waters and these were later approved by the Federal Government. "Water Quality Criteria", "Water Use Classifications," and "Policy Statements" as adopted by the Montana Water Pollution Control Council, together with a map of the surface water classifications are included in Appendix G.

The Water Pollution Council has placed a dual classification on most of the streams in the area. Midvale Creek to East Glacier, Summit Creek to Summit and O'Brien Creek to Neihart and all waters within Glacier National Park except for a portion of Swiftcurrent Creek are classified as A-Open. These streams are used for water supply for drinking, culinary and food processing suitable for use after simple disinfection and removal of natural present impurities. All of the remaining streams have a Class B rating listed as their highest classification. These waters are used for water supply for drinking, culinary and food processing purposes suitable for use with adequate treatment equal to coagulation, sedimentation, filtration, disinfection, and any additional treatment necessary to remove naturally present impurities.

3. Municipal Waste Water Facilities. Presently, waste water treatment is accomplished in waste stabilization ponds in 23 of the listed towns, while another 39 communities have private septic tanks.[9] Three towns - namely, Havre, Chinook and Harlem have waste water treatment plants. It is proposed that Havre construct secondary treatment facilities before the end of 1972.[10] In twenty-five of the communities which have private septic tanks, it is proposed that sanitary sewer collection systems and waste stabilization pond treatment facilities be constructed.[11]

The State Department of Health has worked with municipalities to provide the needed treatment. When needed, enforcement procedures have been initiated; but these have been relatively few. A permit system has been developed that requires all municipalities, industries, and persons discharging wastes to a surface stream to receive a waste discharge permit from the State Department of Health.[12]

The Montana Pollution Council, in 1967, issued a policy statement which indicates that the minimum treatment required for domestic sewage shall be secondary treatment or its equivalent with the understanding that properly designed and operated waste stabilization ponds will meet this requirement. The minimum treatment required for industrial wastes shall be secondary treatment or its equivalent.

4. Municipal Water Supply Requirements. It is estimated that at the present time, approximately 45,200 people live in the towns and municipalities. It is estimated that by 2020, approximately 64,750[13] people will be living in the communities in the Study Area and that of these approximately 39,400 will be served from surface water supplies.

Based upon a per capita usage of 80 gallons per day in the municipalities, it is estimated that in the year 2020 the total municipal water requirement will be 5,820 Acre Feet per year. Of this total, 3,550 Acre Feet per year will be from surface supply and 2,270 Acre Feet will be supplied by groundwater sources.[14]

5. Rural Water Supply Requirements. Population projections for the Study Area show a total population of 86,000 by the year 2020.[15] Approximately 21,250 will be living in rural farm homes. It is estimated that the average annual requirement for the rural domestic supply is 1,920 Acre Feet.

B. STOCK WATER REQUIREMENTS. As pointed out earlier, the diversified farm operation, with both increased crop yield and increased livestock production will add significantly to the stock water requirements of the Study Area. Presently in many areas, farmers cannot support livestock production with the quantity and quality of water that is available. It will be necessary to improve the present water supply in these areas such that the farmers and ranchers may derive the full benefits from diversified operations.

In the eastern counties of the Study Area, where cattle production is predominant, the Bureau of Land Management has been very instrumental in assisting ranchers in the construction of stock water ponds,, wells and springs. The Soil Conservation Service has also given assistance in other parts of the Study Area; however, there is still a lot of work to be done. The Bureau of Land Management is presently constructing approximately 100 stock water ponds annually in the 1 to 5 acre feet capacity.

It is estimated that the stock water requirement for cattle, pig and sheep consumption only is approximately 12,600 acre feet per year in the total Study Area.[16] It is estimated that future stock water requirements could vary from 15,000 acre feet to 20,000 acre feet annually depending upon amount of diversification that is prompted from newly irrigated areas. It must be pointed out that this does not reflect the amount of storage required in stock water ponds since evaporation consumes a large amount of the stock pond water.

C. IRRIGATION WATER REQUIREMENTS. Irrigation requirements vary from year to year, depending upon the rainfall and temperature. Factors which are considered in estimating the annual water requirements are effective precipitation, farm losses and wastes, type of crop, canal seepage, operational wastes, and evaporation from water surfaces.

The consumptive use of irrigation water is normally computed by the Lowry-Johnson method,[17] utilizing precipitation data from weather stations in the area to be irrigated. Only a portion of the summer precipitation, depending on the amount of monthly rainfall, is effective for satisfying consumptive use requirements during the growing season. As precipitation increases, more water tends to run off the ground surface, leaving a smaller proportion effective for crop growth.

Farm losses and wastes from application of irrigation water depend in part on the soil, topography, evaporation, and proficiency of the irrigator. The farm efficiency determined from records of operating projects in Montana indicate the general efficiency of water application to be approximately 60 percent.[18]

Farm delivery requirements for the Central Marias and Big Sandy areas of the Marias-Milk project were estimated to require a farm delivery of 2.19 acre feet per productive acre, while the Milk River Valley lands were estimated to require an average of 2.27 acre feet per productive area.[19]

Utilizing these requirements, the average annual gross diversion per productive acre would be 2.92 acre-feet for the Central Marias and Big Sandy areas and 3.03 acre feet in the Milk River Valley. The diversion requirement estimated in the Blackfeet Indian Plan of Completion report was 3.23 acre feet per acre.[20] For this study, an average diversion requirement of 3.06 acre feet per irrigated acre, (average of above three values) was assumed when better information was not available.

Part of the water diverted for irrigation returns to the stream as ground water flow or surface runoff. Based on the project reports which are available for the area, the average return flow was estimated at .4 of the diverted flow, or 1.2 acre feet per irrigated acre.[21] This was used for projects for which more detailed estimates were not available.

If it is assumed that 1.8 acre feet is required to irrigate one acre (3.0 A.F./Acre diverted - 1.2 A.F./Acre return flow = 1.8 A.F./Acre usage), the total 2,774,264 potentially irrigable acres in the Study Area would require 4,993,700 acre feet per year for full development. The requirement for full irrigation development far exceeds the total for all other requirements.

D. INDUSTRIAL REQUIREMENTS. Industrial water requirements within the Study Area are of limited significance. Industrial requirements are provided in the water supply of the municipalities in most cases with the exception of the oil and gas production that occurs in the western counties.

In most instances the major water requirement is connected with the secondary recovery of oil. Most of the water for this purpose is taken from the Madison formation which yields higher quantities of water of very poor quality and is of little use other than for this purpose. In the Cut Bank area some of the oil operations are taking water from the Virgelle formation. According to a 1967 report, at the present rates of use, depletion of ground water supplies is not imminent.[22]

E. SUMMARY OF WATER SUPPLY REQUIREMENTS. The total water supply requirements for the North Central Study Area are shown in Table V-4. It can be seen from the table that only a small amount of the estimated water supply requirement will be obtained from ground water sources. It can also be seen that water for irrigation purposes far exceeds all of the remaining purposes; however, it should be pointed out that it is imperative that better domestic water supplies be obtained to meet present water standards.

Table V-4

Water Supply Requirements, Year 2020

	Surface	Ground	Total
Municipal	3,550	2,270	5,820
Rural Domestic		1,920	1,920
Stock Water	10,000	10,000	20,000
Irrigation	4,983,700	10,000	4,993,700
Total	4,997,250 AF	24,190 AF	5,021,440 AF

FOOTNOTES - PART V

1 See Table V-1.

2 The "Comprehensive Area Water and Sewer Plan" for the counties had not been released at the time this report was written. They should be available through the Planning and Economic Development Department, State of Montana, in the near future. Information in this report was taken from a preliminary draft of the reports for the counties involved.

3 This projection is based on a linear extrapolation of historic trends of the population for Havre and Glasgow and the assumption that the population of the rest of the area in 2020 will be about the same as it is today.

4 This estimate is based on historic trends away from the farm with most of the increase in municipal population being accounted for in Havre and Glasgow.

5 The State Health Department records of water quality for most municipal supply sources and this information is tabluated in a table: "Chemical Analysis of Municipal Water Supplies."

6 Water quality standards in Montana have been established by the Montana Water Pollution Control Council and have been approved by the Federal government.

7 See pages 62 to 64 of reference V-11.

8 See page 63 of reference V-11.

9 See Table V-I.

10 Secondary treatment or its equivalent is the minimum standard required by Montana's Water Pollution Control Council and the State Department of Health.

11 See Table V-I.

12 The permit system was established by section 69-4807 of the Montana Water Pollution Control Law.

13 See discussion of population projections on page V-1.

14 Estimates based on the assumption that municipalities will continue to use the same source of supply for future expansion, i. e. surface or ground water source.

15 See discussion of population projection on page V-1.

16 This 12,600 acre feet is consumption requirement based on projected stock numbers and "per animal" requirements. Actual water use would be greater due to conveyance losses, evaporation, etc.

17 The Lowry-Johnson method is an attempt to relate evapotranspiration to climatological data. For further information see "Consumptive Use of Water for Agriculture," Trans. ASCE, Vol. 107, pp. 1243-1302, 1942.

18 See references V-11, VIII-8, and VIII-9.

19 Page 66 of reference V-11.

20 See page 12 of reference VIII-9.

21 See references V-11, VIII-8, and VIII-9.

22 See reference VI-13.

PART VI - WATER AVAILABILITY

PART VI

WATER AVAILABILITY

A. SOURCES OF SURFACE WATER

1. General. The main sources of surface water supply in the Study Area are the Marias, and Milk River Basins, both of which are tributaries of the Missouri River.

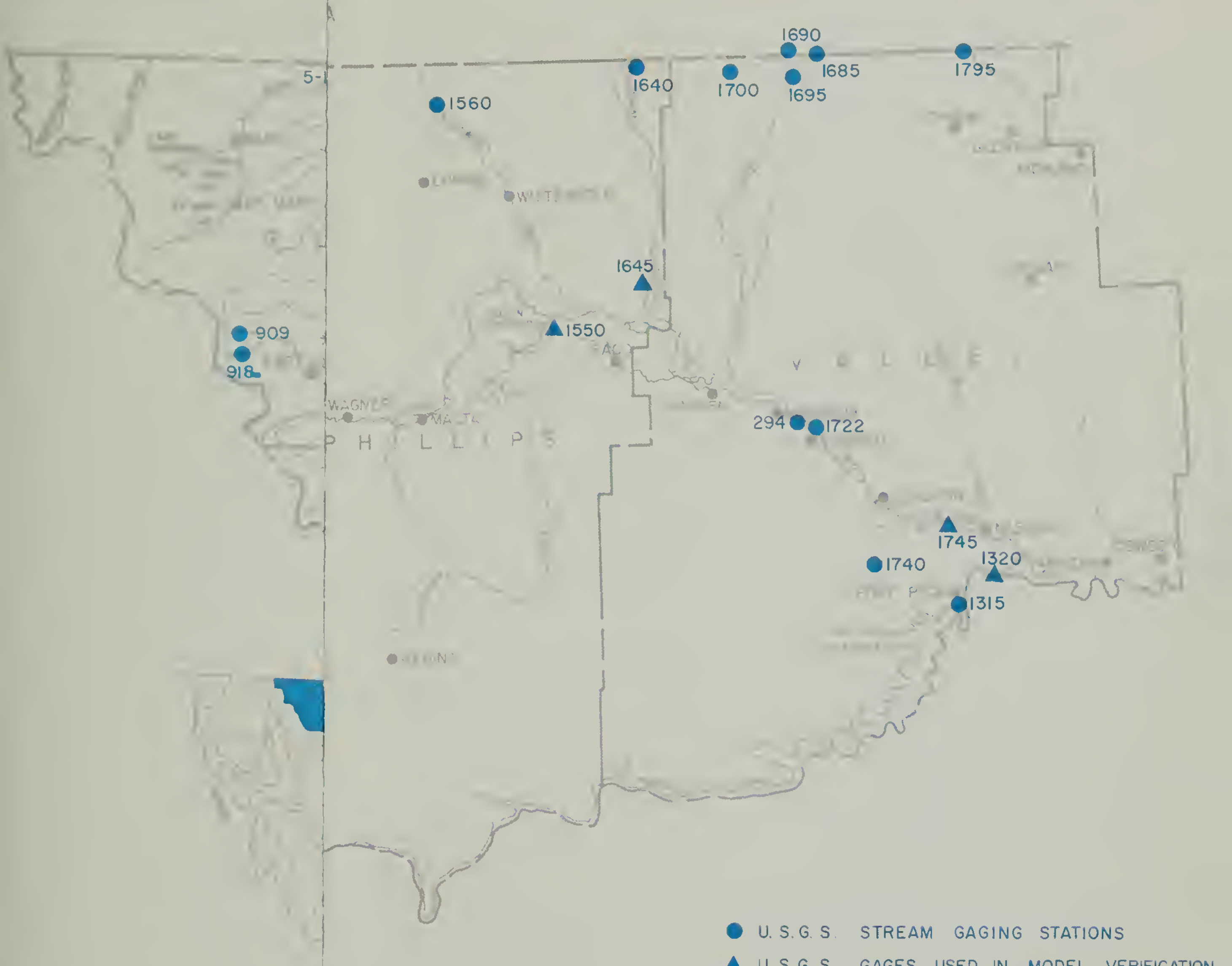
The Marias River with a total drainage area of 6,995 square miles, derives its water from drainage areas high in the mountains of Glacier County in Glacier National Park, Lewis and Clark National Forests and from the plains of the Blackfeet Indian Reservation.

The Milk River watershed with a drainage area of 22,332 square miles, originates farther north than the Marias River watershed in Glacier County close to the U. S.-Canadian border. The river flows from the U. S. through Canada for approximately 120 miles before reentering the U. S. approximately 20 miles upstream of Fresno Reservoir. To supplement the Milk River flows during the irrigation season, part of the St. Mary River flow is diverted to the North Fork of the Milk River via the St. Mary Canal near Babb, Montana. The allocation of the waters of the Milk River and St. Mary River between the U. S. and Canada is governed by international agreements.

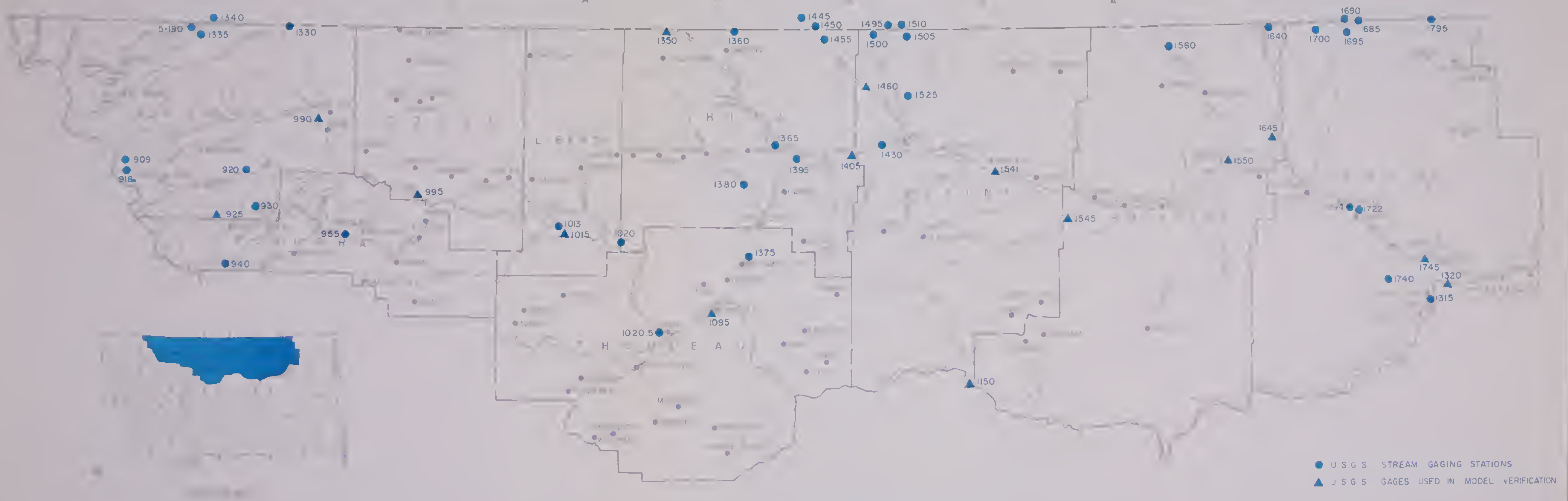
These major rivers and their tributaries are shown on Figure VI-1. Surface water is principally used as a source for domestic, stock, agricultural, recreational and wildlife purposes. Water appropriated for use on most of the streams in the Study Area far exceeds the amount of water available. In the evaluation of surface water requirements, only general consideration has been given to actual appropriation, with most emphasis being placed on determining the most beneficial use of the water available.

2. Drainage Features. Along with the three major rivers, there are many drainage creeks and rivers located in the Study Area. In the western section of the area, these drainage features consist of the St. Mary River, Two Medicine River, Cut Bank Creek, Birch Creek, Dupuyer Creek, Willow Creek, Dry Fork of the Marias River and the South Fork, Dry Fork, Middle Fork, and North Fork of the Milk River. The major drainage structures in this area are Lake Sherburne located west of Babb, Lower Two Medicine Lake near East Glacier, Four Horns Lake near Heart Butte, Lake Frances near Valier, and Swift Reservoir west of Dupuyer.

In the central section of the Study Area, the drainage features are Cottonwood Creek and Sage Creek in Liberty County, Teton River, Highwood Creek and Shonkin Creek in Chouteau County, Big Sandy Creek and



1690
1640
1700
1685
1695
1795
1560
1645
1550
909
918
WAGNER
MALTA
PHILLIPS
294
1722
1745
1740
1320
1315
U. S. G. S. STREAM GAGING STATIONS
U. S. G. S. GAGES USED IN MODEL VERIFICATION



LOCATION OF STREAM GAGING STATION
FIGURE VI-1

Beaver Creek, Peoples Creek, Lodge Creek and Battle Creek in Blaine County. The Frensno reservoir on the Milk River near Havre provides water storage for various downstream uses.

The eastern section of the Study Area has several significant drainage features. They are Whitewater Creek, Frenchman Creek and Beaver Creek in Phillips County and Rock Creek, Porcupine Creek and Willow Creek in Valley County. Also located in this section are Lake Bowdoin, Nelson Reservoir and Ft. Peck Reservoir.

B. SURFACE WATER AVAILABILITY

Rainfall through the central and eastern section of the Study Area is fairly constant with an average annual rainfall of approximately 13 inches;[1] however, in the western sections near the Continental Divide, the annual accumulation of rainfall reaches a maximum average of about 40 inches, due primarily to orographic effects. Annual accumulation of snow fall in the eastern and central sections of the Study Area is fairly constant at an average of 40 inches; however, accumulations approach 100 inches in the western sections near the Continental Divide. Considering the low annual rainfall predominant throughout most of the Study Area, it can be generally concluded that the area is semiarid in nature.

Annual runoff resulting from most of the area amounts to only about one-half inch per year. Runoff from some western areas approaches 20 inches,[2] but this is primarily due to the high annual rainfall and snowfall associated with the mountains. Flow in streams is seasonal in nature with periods of high runoff in spring and early summer. Rainfall is primarily responsible for the high runoffs which occur in early spring while snow melt is principally responsible for the late spring and early summer peak flows. Numerous tributaries throughout the area are dry during part of the year.

A comparison of the duration curves of stream flow constructed for the Missouri, Milk and Marias Rivers at various gaging stations in the Study Area is shown on Table VI-1[3] and on Figures VI-2 and VI-3. The Q10, the 10 percentile flow, represents the flow that is exceeded ten percent of the time, the Q50 represents a flow that is exceeded fifty percent of the time, and the Q90 represents a flow that is exceeded ninety percent of the time. The Q90 is commonly accepted to represent the base flow of the stream, while the Q10 is generally accepted to represent the flood flows of the stream.

Study of the results of the duration curves summarized in Table VI-1 reveals:

1. The average stream flow of all three streams occurs between 16% and 34% of the time, leading to the conclusion that the stream's flows are highly variable.

Numbers refer to footnotes located at the end of this chapter.

Beaver Creek, Peoples Creek, Lodge Creek and Battle Creek in Blaine County. The Frensno reservoir on the Milk River near Havre provides water storage for various downstream uses.

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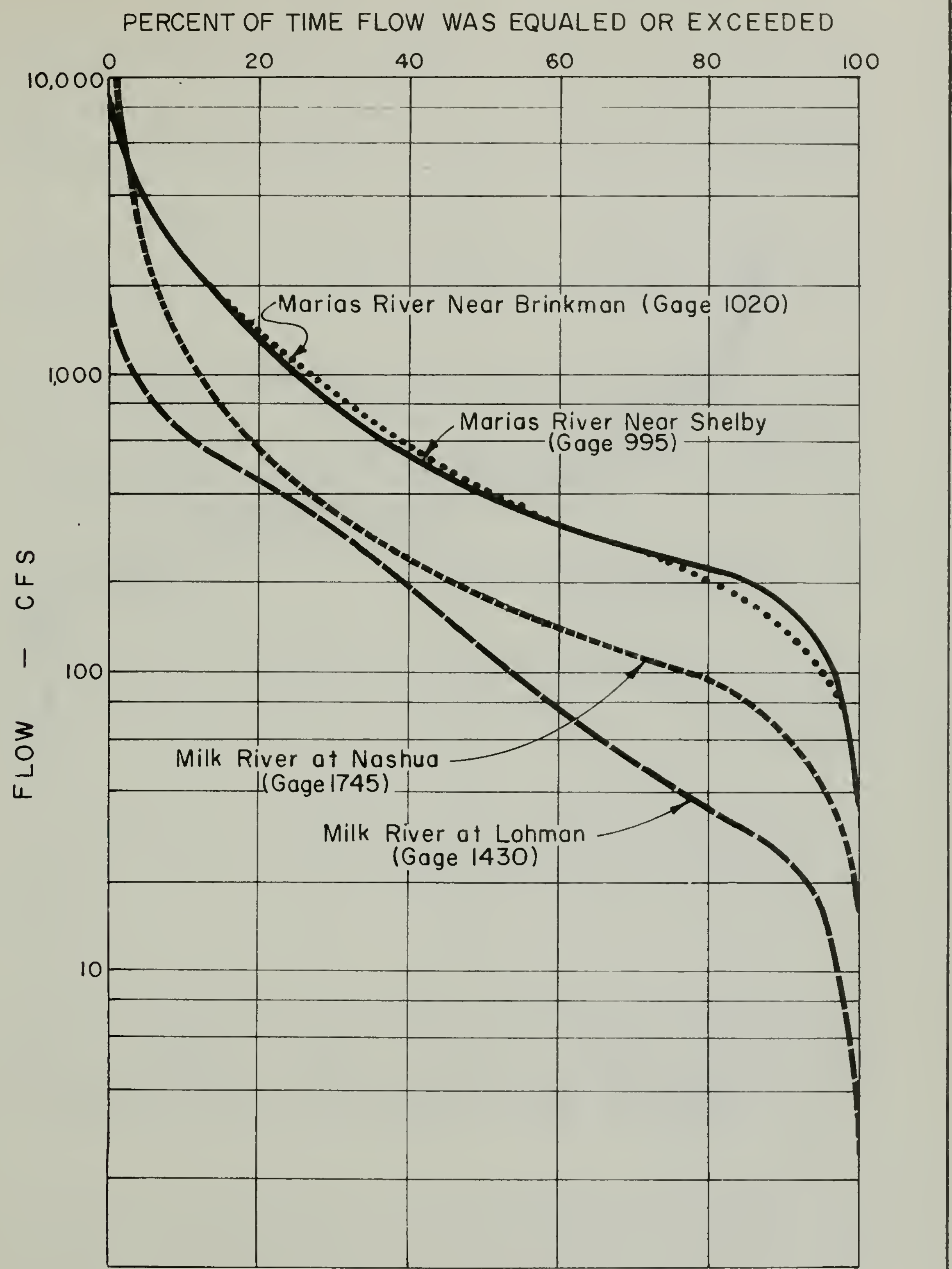
Numbers refer to footnotes located at the end of this chapter

SURFACE WATER AVAILABILITY

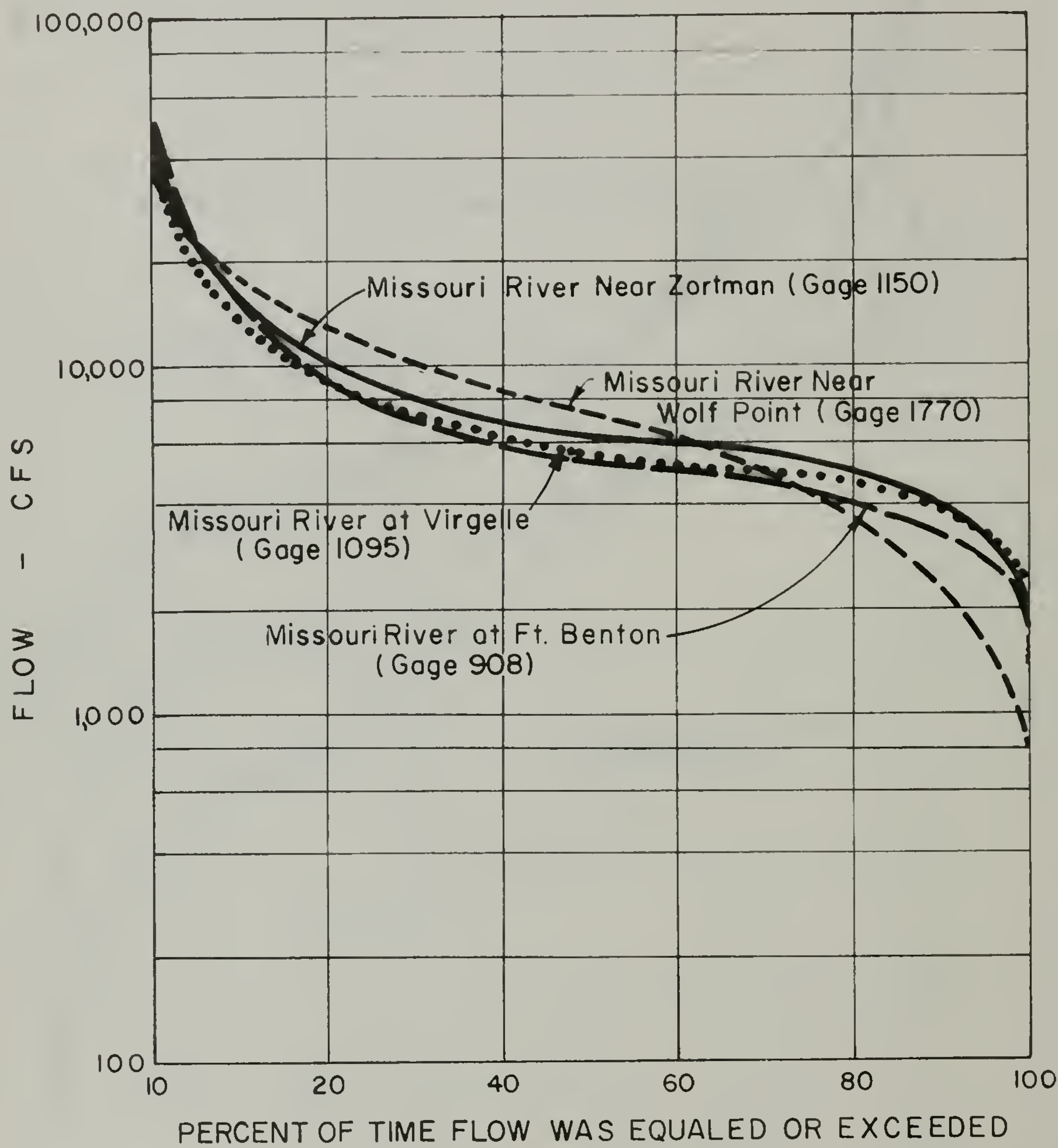
TABLE VI-1

LOCATION	GAGE NO.	PERIOD OF RECORD	DRAINAGE AREA(MI.)^2	Q_{10} (CFS)	Q_{50} (CFS)	Q_{90} (CFS)	Q_{AVG} (CFS)	% OF TIME Q_{AVG}	Q_{10} MI.2 (CFS/MI.2)	Q_{50} MI.2 (CFS/MI.2)	Q_{90} MI.2 (CFS/MI.2)	Q_{AVG} MI.2 (CFS/MI.2)
MISSOURI RIVER NR. WOLF.PT.	1770	1938-63	82,290	18,000	7,000	2,200	9,877	30	0.2187	0.0851	0.0267	0.90
MISSOURI RIVER NR. ZORTMAN	1150	1935-63	40,763	15,000	6,100	3,900	8,855	24	0.3680	0.1496	0.0956	0.206
MISSOURI RIVER @ VIRGELLE	1095	1936-63	34,379	14,000	5,500	3,800	8,125	24	0.4072	0.1600	0.1105	0.226
MISSOURI RIVER @ FT. BENTON	908	1891-1963	24,749	25,000	5,200	3,300	7,605	25	0.6060	0.2101	0.133	0.304
MILK RIVER @ NASHUA	1745	1940-63	22,332	1,250	180	64	694	16	0.0560	0.0081	0.0029	0.0306
MILK RIVER @ LOHMAN (SUBSEQUENT TO FRESNO)	1430	1939-51	6,166	650	120	20	262	34	0.1054	0.0195	0.0032	0.0425
MARIAS RIVER NR. BRINKMAN (PRIOR TO TIBER OPERATION)	1020	1922-55	5,907	2,500	400	140	952	27	0.4232	0.0677	0.0237	0.161
MARIAS RIVER NR. SHELBY	995	1912-63	2,724	2,500	400	160	949	26	0.9178	0.1468	0.0587	0.344



MONTANA CONSERVANCY DISTRICT STUDY
STREAMFLOW DURATION CURVES

FIG. VI-2



MONTANA CONSERVANCY DISTRICT STUDY
STREAMFLOW DURATION CURVES

FIG. VI-3

2. For the most part, the specific base flow Q90 in cubic feet per second per square mile of drainage area of the Missouri River is about 30 times the specific base flow of the Milk River and about 3 times the specific base flow of the Marias River. Since base flow is that portion of the flow that is contributed by groundwater, streams with a low specific base flow generally have a small portion of their total flow derived from groundwater.

3. The specific average flow (Q50 in cfs per square mile of drainage area) of the Missouri and Marias Rivers are quite similar and are approximately 10 times greater than the specific average flow of the Milk River.

4. In an average year, 523,400 acre-feet flows from the Milk River watershed and 689,000 acre-feet flows from the Marias River. These flows are based on USGS data from 21 years of record for the Milk River and 52 years of record for the Marias River. Analysis of the data provided by gage 1745 indicates that although flows are highly variable, an average flow of 523,400 acre-feet/year is available in the Milk River at Nashua. Although an average of 523,400 acre-feet/year of water passes Nashua each year, the Bureau of Reclamation has indicated that existing storage in Fresno Reservoir and flow supplied from the St. Mary River is fully developed at the present time.[4] In general, it would appear that water is available at times when it is not needed and is not available when needed. The limited regulation provided by Fresno Dam does not appear sufficient and additional regulation of this water would appear essential to further development of the river.

It is significant to note here that there is additional water available in the lower portion of the Milk River. To make this water available when needed, additional storage and flow regulation sites will be required together with a coordinated water management effort along the entire Milk River.

A general evaluation of the volume of water available in the Study Area was made by comparing the amount of water flowing out of the Study Area with the amount flowing into the area. The difference represents the net amount of water which originates in and flows from the area under the existing level of development. In the average year this amounts to about 1.6 million acre-feet.[5]

Because there are minimum flow requirements for water quality control and because of the time and spatial variation of the flows, it is not possible to put all of this water to beneficial use. An evaluation of the flow system was made considering these constraints, using the linear programming optimization model. Results from this model study supplemented with engineering evaluations indicated that an additional 644,000

acre-feet from the Milk, Marias and Missouri Rivers could be used for irrigation and other purposes.

Of this total, 318,000 acre-feet is supplied by the Marias River, 236,000 acre-feet by the Milk River and 90,000 acre-feet by the Missouri River. These studies considered stream flow supplies of 65% of average annual flows. Details of the derivation of available surface water indicating the amounts allocated to water quality control is given in Part X, page 2 of this report.

Up to an additional 183,000 acre-feet could be available to the area from the St. Mary River region as discussed in Part X, bringing the total amount of surface water which could be developed in the Study Area to 827,000 acre-feet. A large share of this additional 183,000 acre-feet would come from the Waterton-Belly area, or more likely through an exchange with Canada of Waterton and Belly River water for additional flow from the St. Mary River. This potential source of additional water for an area otherwise devoid of a good source should be evaluated further as a part of any additional studies of a possible conservancy district.

C. WATER AVAILABILITY AT STRUCTURES. The U. S. Geological Survey has maintained gages throughout the Study Area for many years, however, many of the gages are intermittent in type and do not record flows during the winter or other times of the year. The gages with the longest period of record and with the least amount of upstream regulation were selected to establish a relationship between average annual flow and drainage area for the three main river basins and their tributaries. A plot of average annual flow versus drainage area for gages within basins of similar hydrologic conditions results in a straight line plot on log paper and is shown in Figure VI-4. Such a relationship usually exists in regions where hydrologic factors such as precipitation, vegetation cover and geologic conditions are relatively similar.

Average flows were estimated at the locations of all existing and proposed structure sites by utilization of available stream gage information. Since stream flow records were seldom available at the proposed or existing structure sites, the area-flow relationship established for each of the tributaries and main streams was used to establish the flow at the desired points. The general relationship which was used for computing flows at structure sites from the flows at gaging stations is expressed as follows:

$Q_g = Q_p (A_p/A)^n$ where:

Q_g = flow at gaging station

A_g = area at gage, A_p = area at structure

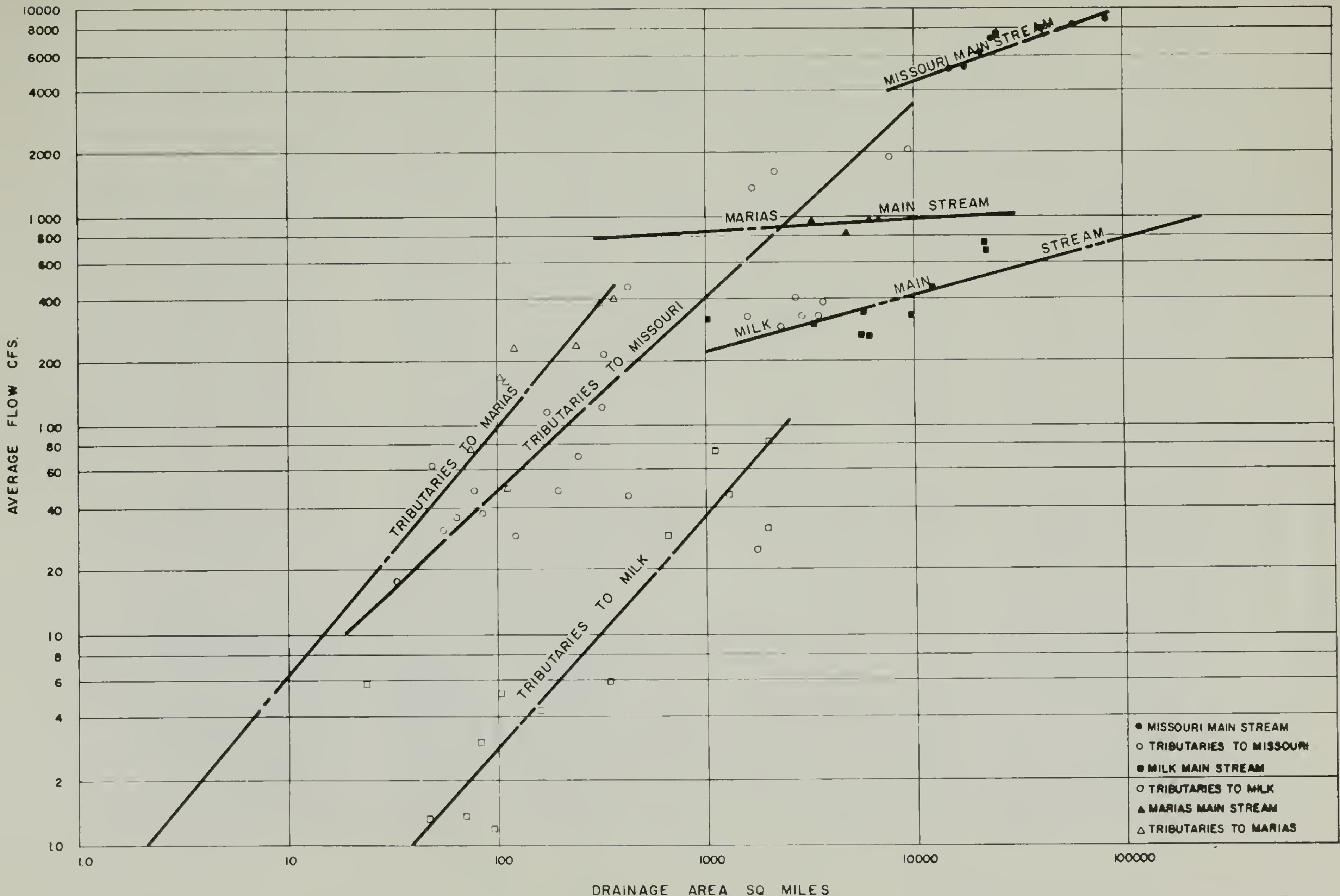


FIG. VI-4

MONTANA CONSERVANCY DISTRICT STUDY
DRAINAGE AREA VS AVERAGE FLOW

Q_p = flow at structure

n = exponent determined from plots in Figure VI-4.

In choosing a stream gage to estimate the available flow at a proposed structure site, an amount of discretion was exercised since the number of available gages were limited. Gages were chosen within the same drainage basin as the proposed site if possible, and as close to the latter as possible. However, those gages located on the main stream could not in general be used to estimate flows at a structure on a tributary because of the difference between topography, rainfall and surface cover in the tributary area compared to that in the main stream area.

Seasonal flows at each structure were established by correlation with the seasonal flows at the gages. The seasons selected for study and evaluation in the systems model consisted of two periods, October through April, and May through September. The period October through April represents the non-irrigation or supply period; the May through September period is the irrigation season. Monthly flows at the gages were averaged over these two periods to result in a generalized two-season hydrologic flow at the gage. These hydrographs were transferred to the specific structure site by the area-flow relationship previously established.

The average water availability at each of the structures was evaluated by first adjusting the gage data to reflect unregulated or natural flow conditions. Flows established in this manner have not taken into consideration existing irrigation uses and reservoir regulation, consequently adjustments for these users were applied to the flow estimates to verify existing gage data. This step is referred to as "model verification." In the present study, this was accomplished by manual computation. Adjustments were applied to estimated flows until measured flow conditions during the periods May through September and October through April were duplicated at all pertinent gaging stations. Fifteen gaging stations were used for this verification purpose and are shown on Figure VI-1.

The average flow of a stream is the maximum quantity of water that could be developed by an impounding reservoir. However, factors such as limiting topographic conditions, evaporation and seepage losses and the impracticality of using extensive yearly carryover storage, tend to limit the developable flow to a flow less than the average. Estimates of the percentage of the average flow that could possibly be developed, were made by evaluation of the monthly mass flow curves for the Milk River at the following locations:

Gage Location	Years of Record
1. Nashua	1940-68
2. Vadalia	1915-39
3. Lohman	1923-25, 1935-39 (Prior to Fresno)
4. Lohman	1939-51 (Subsequent to Fresno)
5. Harlem	1959-1968

The drought periods of the mass curves were evaluated considering 2, 3 and 4 years of carryover storage. The results of this evaluation are shown in Table VI-3.

Table VI-3

			Percent of Avg. Flow For Carryover Storage		
Location	Gage	Years of Record	2 yr.	3 yr.	4 yr.
Nashua	1745	1940-68	35%	56%	58%
Vandalia	294	1915-1939	27%	30%	42%
Lohman	1430	1923-25, 1935-39	79%	91%	
Lohman	1430	1939-51	71%	75%	86%
Harlem	1541	1959-68	56%	56%	56%

In reviewing Table VI-3 it should be noted that the Lohman gage appears to indicate artificially high yields. This is due to the fact that the periods of record for the Lohman gage do not include the two driest years of record which occurred in 1961 and 1931.

Analysis of the Marias River studies by the Bureau of Reclamation for the Marias-Milk project has indicated that the Tiber Reservoir would develop approximately 66% of the average flow of the Marias. This study considered the Indian depletions, low flow releases and irrigation requirements.

As a result of these analyses, this study considers 65% of the average flow to represent the yield that could be developed by an impounding reservoir. It should be noted that the actual percentage of the average flow that could be developed at each individual site may vary from 65% and will depend upon the benefits and costs of providing the yield. For example, a reservoir sized to yield more than 65% of the average annual flow may be justified so that more water can be utilized during most years, even though the reservoir could not be completely filled during some particularly dry years. This arrangement, however, may result

in greater benefits to the area served than if the yield were limited by the drought year. Therefore, the estimate of 65% of average flow should be interpreted as an approximation of the quantity of developable water. This percentage is considered to represent a lower limit estimate of developable water.

Average flows previously estimated at the existing and proposed reservoirs were adjusted to reflect estimated developable flows. The hydrologic flows determined in this manner were input to the mathematical model and are assumed by the model to be repeated every year.

D. SOURCES OF GROUND WATER

1. General. Groundwater, as defined here is water in the zone of saturation. The saturated zone may be viewed as a natural reservoir or system of reservoirs, whose capacity is the total volume of the pores or openings in the rocks that are filled with water.

The thickness of the zone of saturation varies from a few feet to many hundreds of feet. Factors that determine its thickness are: local geology, the availability of pores or openings in the formations, and the recharge and movement of water within the zone from areas of recharge towards areas of discharge.

Groundwater is the most widespread source of domestic and stock water in the Study Area. Groundwater has several inherent advantages over other sources of water. Among these are its widespread occurrence, uniform temperature, and comparative freedom from pollution. The dissolved minerals in groundwater sometimes affect its usefulness for various purposes. If one or more of the minerals are in excess of the amount that can be tolerated for a given use, some type of treatment may be applied to change or remove the undesirable mineral, so that the water will serve the intended purpose.

The North Central Montana area forms the panhandle of a groundwater region known as the Glaciated Central Lowland region. This region at one time or another has been overrun by continental glaciers moving southward from Canada. The glacial deposits in the Study Area are generally fine-grained and of low permeability.

2. Groundwater Wells and Springs. The groundwater supply capability within the Study Area has not been thoroughly investigated. Several special studies have been made to determine groundwater supply in localized areas. A study by Everett A. Zimmerman entitled "Water Resources of the Cut Bank Area" investigated the impact on well yields in the Cut Bank area associated with proposed increases of well water use for secondary recovery of oil. Another report by Everett A. Zimmerman entitled "Geology and Ground Water Resources of Northern Blaine County" investigates this area for the availability of water for

irrigation, stock watering and domestic use. Groundwater resources information for the remainder of the nine county area has been provided through the Montana Bureau of Mines and Geology, the Montana Water Resources Board and the State Health Department. Use of existing groundwater data and the gathering of additional data will be needed to provide a basis for selecting aquifers and drilling depths to obtain an adequate quantity of water having suitable quality.

3. Aquifers. The availability of groundwater in the Study Area is directly related to geologic events which took place millions of years ago. Generalized geologic conditions for the eastern and western counties of the Study Area are presented in Figure VI-5 of this report. Generally speaking the same geologic formations are present in every county - the exception being Glacier County where some of the formations are referred to by different names. However, there is no certainty of finding a particular aquifer at a specific site and a specific depth. The aquifers are described individually in sequence of geologic age, the youngest or most shallow first and the oldest or deepest last.

Alluvium (Quaternary) is stream and river deposits, composed of silt, gravel, and clay, mixed and interbedded, of recent geologic age and normally unconsolidated or only weakly cemented. The Milk River valley contains two alluvial series. The lower series is Missouri River alluvium, and the upper is Milk River flood plain alluvium. Both series carry some water, frequently insufficient in quantity and poor in quality. Most of the other major streams in the area, such as the Marias River and Cut Bank Creek, have narrow belts of thin floodplain deposit.

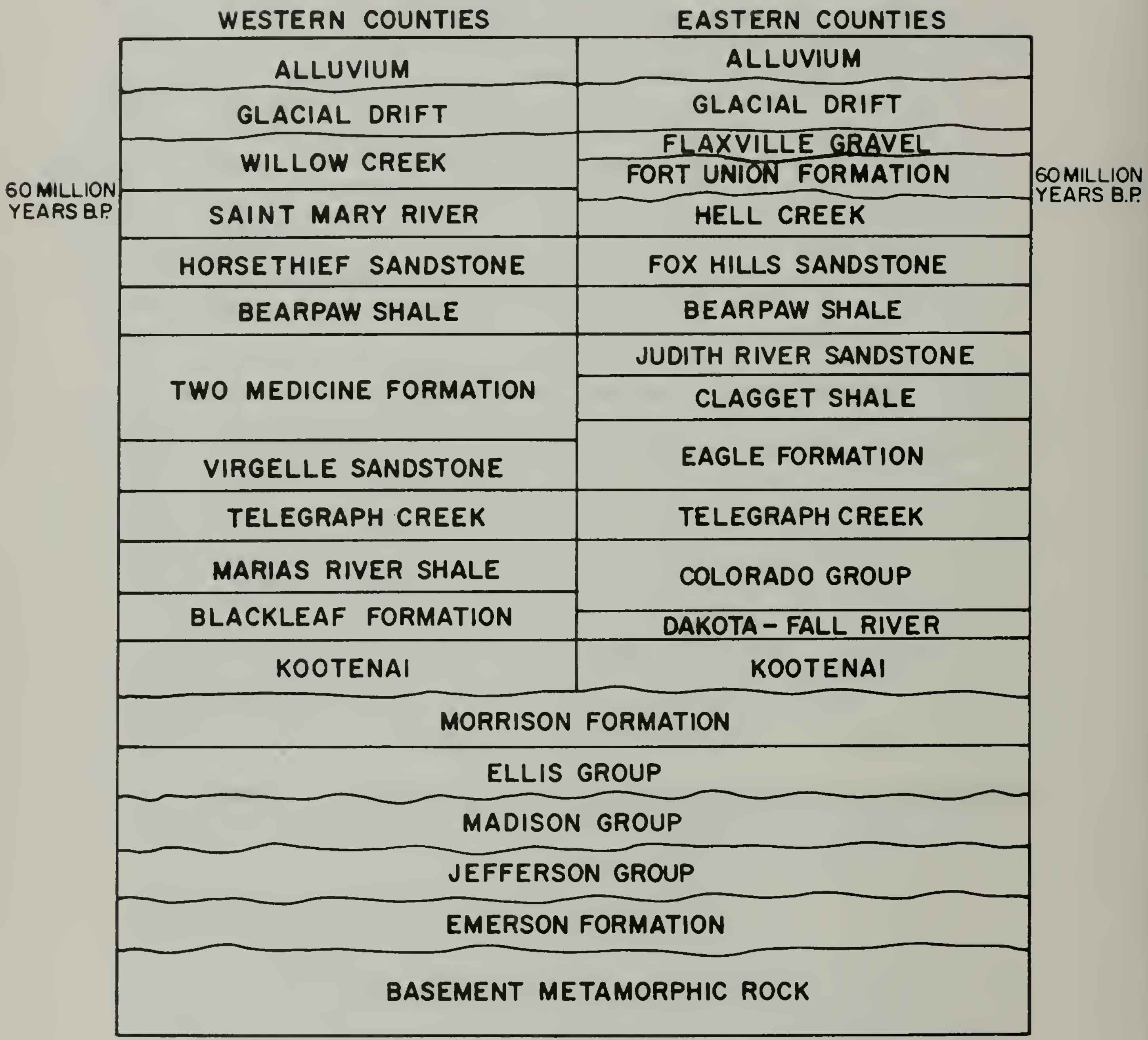
Alluvium in the upper reaches of the tributaries and alluvial fans are more prospective as sources of groundwater than floodplain alluvium. Similarly, colluvium of the high benches and upper slopes is a potential aquifer but of unknown groundwater potential.

Glacial Deposits (Quaternary). The glacial till that mantles much of the area seldom is an extensive aquifer due to the high percentage of impervious material present.

Ancient valley fill underlies the Milk River floodplain in a pre-glacial Missouri River channel and is a heterogeneous accumulation of glaciofluvial clastic material which collected in valleys and depressions during the glacial epoch. The fill includes gravel and coarse-sand aquifers of limited extent. These aquifers provide adequate water supplies for domestic and stock needs and most likely would provide moderate yields, perhaps in excess of 300 gpm (gallons per minute) locally from large-diameter wells. The preglacial Marias Valley fill has discontinuous lenses of gravel and sand which generally are moderately productive, but these are not extensive aquifers and therefore are considered incapable of large sustained yields. The valley-fill water quality generally is not as good as that of alluvial-fan water, but the water is suitable for livestock and can be tolerated by humans. Glacial

FIG. VI-5

GENERALIZED GEOLOGIC COLUMNS



materials appear in the form of terminal and ground moraines, outwash channels, and lake sediments. Glacial moraine mixtures of boulders, sand, gravel, silt and clay generally yield small quantities of water to wells, but water quality is often unsuitable for domestic use. Outwash channel deposits of sand and gravel will yield moderate to occasionally large quantities of water usually suitable for domestic and stock use. Lake sediments consisting of fine-grained silt, clay and sand, will yield small quantities of groundwater.. In general, the glacial deposits are considered to be a poor source of groundwater.

Flaxville Gravel (Tertiary). Approximately 100,000 acres of the Big Flat elevated plateau in northeastern Blaine County is underlain with the Flaxville formation. The Flaxville formation consists of about 75 feet of sand and gravel and yields moderate to large quantities of good quality water to wells. Water for domestic, stock and limited irrigation use is available from this formation. The eastward continuation of the Big Flat in Phillips County is a dissected terrace of unknown groundwater potential. In Valley County the thickness of the Flaxville gravel varies from a few feet to a hundred feet. The maximum reported well-yield from the gravel is 100 gpm while 10 gpm is most commonly reported.

Fort Union Formation (Tertiary) is a sequence of relatively soft light-colored sandstones, siltstones, and shales, with a few coal seams. Rocks of this sequence are the youngest bedrock strata. Water from this formation generally is relatively low in amount of total dissolved solids but may have a high sodium content. Well yields are 5 to 30 gpm.

Hell Creek-Fox Hills (Cretaceous) is a sequence of brown sandstones and shales. The interval has an eroded thickness of less than 100 feet presumably to as much as 600 feet thick. Water is pumped through wells 75-350 feet deep, at rates of 5 to 30 gpm.

Bearpaw Shale (Cretaceous) is an interval of blue-black shale of varying thickness due to erosion, as much as 1,000 feet thick underlying younger bedrock, and not normally an aquifer. Water passing over or through the Bearpaw shale will eventually carry in solution sodium leached from this formation.

Judith River Formation (Cretaceous) consists of interbedded sandstones, clays and shales, and coal seams, 400 feet or more in total thickness. The sandstones are gray and tan, fine-grained, lensatic and discontinuous. The more massive sandstone members are 40-50 feet thick and are found in the basal part of the formation. Water from the Judith River is reported of good quality, suitable for livestock and humans at some well sites but only tolerable by humans at others. Judith River aquifers are found at depths of 75-600 feet, but more commonly at depths of 100-300 feet. Traces of natural gas are sometimes found in the formation.

Claggett Shale (Cretaceous) is an interval of shale similar to the Bearpaw shale and not normally an aquifer. A complete section is reported

to vary in thickness from less than 200 feet to more than 700 feet locally in the plains area.

Eagle Formation (Cretaceous) underlies the Claggett shale and is 200+ feet of buff-colored silty sandstones and shales in the upper part and a massive sandstone 35 feet to 100 feet thick at the base. The basal sandstone is distinctive enough to be named the Virgelle member, and it is a fair aquifer even though the water is highly mineralized. Total dissolved solids are in the range 1,000-2,500 ppm, and as high as 5,000 ppm locally. Artesian aquifers in the Eagle are found at depths of 250 feet to 1,500 feet. Commercial amounts of natural gas are found locally in this formation.

Telegraph Creek Formation (Cretaceous) consists of fine-grained sandstone and dark-gray shale and yields small amount of poor quality water.

Colorado Shale (Cretaceous) is approximately 1,500 feet of bluish-gray and gray-black shale with sandstone lenses and stringers, none of which is considered an aquifer. The commercial accumulation of natural gas in the Bowdoin field occurs in silty sandstone lenses in this interval, at depths of 700 to 900 feet below the surface.

Kootenai Formation (Cretaceous) is part of the Dakota-Lakota sequence which is 300 to 400 feet of sandstones and shales containing some of the best artesian aquifers in Central Montana. Only a small number of wells in the area are reported using Kootenai water, and this from a depth in excess of 2,500 feet. Depth to aquifer is the deterring factor in widespread usage of what could prove to be an excellent local groundwater source.

Ellis Interval (Jurassic) is a group of limestones, sandstones, and shales which attain a collective thickness of over 400 feet; local potential aquifers may be present. The basal unit in this sequence is capable of producing commercial amounts of natural gas and oil.

Madison Limestone (Mississippian) is approximately 1,000 feet of light-colored limestones sometimes having cavernous porosity in an upper massive unit. Where this unit has been penetrated and tested by deep exploratory wells large quantities of water have been recovered. The Madison apparently has the potential for large-scale irrigation, but a specific well site may encounter an impervious rock section. Deep-well control is not dense enough to project the Madison potential to a specific site everywhere in the Study Area. The amount of recharge available to the Madison is not accurately known at this time. The Madison provides large quantities of water for the secondary recovery of oil in the area. Madison water reportedly is also used for "health and recreation" and small-scale irrigation in north-central Montana. Depth to aquifer has deterred greater development for non-industrial use.

Pre-Mississippian Rocks include those of Devonian and Cambrian age. Within the more than 1,200 feet of Devonian section, the Jefferson formation contains carbonate intervals which probably could provide small to moderate well-yields. Development has not been attempted due to the risk and cost involved. Below the Devonian are rocks of Cambrian age, among which are limestones and sandstones that may be water bearing. The deeper pre-Cambrian section has not been explored but could be water-bearing in fractures and cavities at depths exceeding 5000 feet below the surface.

Pre-Cambrian - metamorphic and igneous rocks underlie the softer sedimentary section, and could be water-bearing in fractures or formational contacts but normally are not considered aquifers.

In the western counties, particularly Glacier, some of the geologic formations are different or known by different names. The uppermost intervals in the western counties are the alluvial and glacial deposits, similar to those in the eastern counties. Lower layers in sequence of geologic age are:

Terrace Gravels (Quaternary/Tertiary) have a wide geographic distribution in the western counties as well as the rest of the Study Area, both as small isolated patches and relatively large remnants of fluvial deposits. The gravels have been derived mainly of material eroded from the mountains and are mostly unconsolidated or poorly cemented. There are several terrace levels, flat-topped, gently sloping away from the mountains. The highest levels (or benches) are near the mountain front and now rise hundreds of feet above present streams. Sediments that previously have been described as "undifferentiated Tertiary rocks," which were in part laid down in lakes, streams, and alluvial fans at valley elevations, are included in this category.

The larger gravel remnants are sources of groundwater, and well yields of 1 to 25 gpm are reported, from gravel thicknesses of 6 to 80 feet. Many of the springs in Glacier County for which there are records of groundwater appropriations discharge from terrace gravels.

Willow Creek Formation (Tertiary) is at least 720 feet thick and consists chiefly of varicolored clay and soft sandstone, predominantly red in color. There are no records of wells completed in this formation.

St. Mary River Formation (Cretaceous) is about 1,000 feet of gray and greenish-gray clay and shale, with sandstone interbeds. There is one well of record completed in this formation in Glacier County, reportedly pumping 112 gpm from a total depth of 10 feet.

Horsethief Sandstone (Cretaceous) is massive, light-gray, fine-to-coarse grained, 90 to 360 feet thick in the outcrop. Several wells reportedly have been completed in this sandstone, pumping 8 to 15 gpm from total depths of 55 to 240 feet. Based on available information the specific capacity of a well completed in the Horsethief normally is considerably less than 1 gpm per foot of drawdown, although one well reportedly pumps 15 gpm from a depth of 229 feet with no drawdown.

Bearpaw Shale (Cretaceous) is about 500 feet of dark colored shale and not normally an aquifer.

Two Medicine Formation (Cretaceous) varies in thickness from about 300 feet to 2,000 feet. The upper section is greenish-gray shale with irregular sandstone stringers and lenses, while the lower 250 feet is predominantly buff-colored sandstone equivalent to the upper Eagle formation. The Two Medicine formation outcrops over a large area in eastern Glacier County (partially mantled with glacial till) and is a widely used aquifer. Groundwater is available in several sandstone intervals within the formation but mostly in the Eagle equivalent. The Two Medicine is thought to be hydraulically connected to the underlying Virgelle sandstone at many places. The majority of Two Medicine wells are drilled more than 100 feet deep, and some are in excess of 400 feet. Reported yields are in the range of 2 to 250 gpm. The quality of Two Medicine groundwater varies considerably from well to well. Total dissolved solids have been calculated in amounts of 238 ppm to 5,225 ppm (the latter value may represent water produced from both the Two Medicine and the Virgelle). Total dissolved solids in amounts greater than 1,200 ppm are frequently reported. Two Medicine water is relatively high in amounts of sodium, bicarbonate, and sulfate.

Virgelle Sandstone (Cretaceous) is a massive gray to buff sandstone, about 160 to 180 feet thick, and a major aquifer in eastern Glacier County. Wells have been drilled as deep as 400 feet to reach this aquifer and yields of 20 to 120 gpm are reported. Greater yields, probably as much as 250 gpm, could be expected locally from properly constructed wells. At least 8 wells originally were drilled to provide groundwater from the Virgelle for industrial use. In 1967, approximately 113 acre-feet of water from the "Eagle" (Virgelle) were used in the secondary recovery of oil.

The quality of water in the Virgelle is similar to that in the Two Medicine. Amounts of total dissolved solids range from 600 ppm to 5,000 ppm, mostly in the range of 1,000 to 3,000 ppm. Sodium, bicarbonate, and sulfate are of relatively high concentrations.

Colorado Shale (Cretaceous) is a sequence of shales and local sandstone beds, about 500 feet thick on the Kevin-Sunburst Dome and over 2,000 feet thick (including 170 feet of Telegraph Creek formation between the Virgelle and Colorado shale) under younger bedrock. Even though shale is not normally an aquifer, the Colorado shales do contain interbeds of

sandstones which can be water-bearing, and some water reportedly is obtained through wells completed in the "shale." The upper part of the Colorado, where present, is known as the Marias shale and the lower more sandy part as the Blackleaf. Water might be obtained locally from sandstones within the Blackleaf. However, the risk of prospecting for water is much greater in the Colorado than in sandstones such as the Virgelle, and yields most likely would be smaller and the water more mineralized.

The Kootenai and older formations are similar to the descriptions given earlier for the eastern counties.

E. GROUND WATER AVAILABILITY

The volume of water stored underground in the Study Area is far greater than the amount available from surface water. Extensive development of this groundwater has been generally limited due to:

1. low yields.

2. poor quality.

3. high costs of development.

A general description of the groundwater aquifers and their yield and quality can be found in the preceding section of this report. Additional information is contained in the water resource survey reports of the individual counties in the Study Area. As a consequence of these reports and their results, it can generally be concluded that:

1. small scale development of the springs and/or groundwater might be possible to service comestic and stock water supplies;

2. yields from groundwater sources are limited throughout the Study Area due to low permeability of the aquifers and the limited sources and amounts of recharge;

3. the areal extent of aquifers having adequate yields of suitable quality water appears to be limited;

4. large scale development of the groundwaters appears to be economically infeasible at this time in comparison to the cost of development of surface waters.

This is not to say that groundwater will not be of increasing importance in the future. In fact, the factors which have prevented any extensive development of groundwater could change in a relatively short time. Advances in technology for the improvement of water quality from groundwater sources may provide an economic means for providing

water of suitable quality. Some of the more extensive geologic formations which underlie the area at depths in excess of 2,000 feet, such as the Kootenai formation and Madison limestone, are capable of large yields of reasonably good quality water. At present, economics deters development, but economic conditions in the future together with improved well development methods may make these deep aquifers important sources of water in areas such as northern Toole and Liberty Counties which are nearly devoid of good sources of water.

FOOTNOTES - PART VI

[1] Mean Annual Precipitation Map in "Water Resources Investigations in Montana, 1969," U. S. Geological Survey.

[2] Average Annual Runoff Map in "Water Resources Investigations in Montana, 1969," U. S. Geological Survey.

[3] Table VI-1 gives information derived through an evaluation of historic USGS stream gage records.

[4] See Field Draft of Marias-Milk Project Report, USBR, Copy No. 10, page 69.

[5] This 1.6 million acre-feet is the sum of the average annual flows shown on page 3 in the section: Summary, Conclusions & Recommendations (less the 240,000 A. F. shown available in the Waterton-Belly Rivers).

PART VII - EXISTING AREA WATER DEVELOPMENT

PART VII

EXISTING AREA WATER DEVELOPMENT

A. EXISTING SURFACE SUPPLY AND IMPOUNDMENT WORKS. Exhibits in Appendix H list the existing projects within the boundaries of the Study Area. All reservoirs of 50 acre-feet or larger are tabulated along with the size, location, purpose, and constructing agency of the reservoir. All 320 existing projects listed in the Appendix have been placed in the optimization model of the Study Area, either individually or lumped together with several other projects. The model is described briefly in Section IX of this report, with additional details in Appendix A. Detailed operational characteristics for all 320 existing projects were not available. For larger projects, such as those listed in Section B below, detailed information was available and this was used in the model wherever possible. When no information was available the operation of existing projects was inferred from the gaged stream flows. As an integral part of any irrigation or municipal supply and impoundment project (dam) there must be a distribution system. This type of system is generally a system of canals, a pipeline, existing waterways with diversion structures, pumping facilities or a combination of these systems. These distribution systems have not been described in any detail in this report. It is implied that if a distribution system is necessary it exists as a part of the supply and impoundment project as shown. Flood control and stock watering dams generally do not require distribution systems.

B. PRINCIPAL EXISTING IMPOUNDMENT AND SUPPLY WORKS

1. Fort Peck Dam and Reservoir.[1] The Fort Peck Dam and reservoir is the most important impoundment project in the Study Area. The dam, placed primarily by hydraulic earth fill, is one of the largest in the world and was constructed using 125,600,000 cubic yards of earth plus 3,910,000 cubic yards of gravel.

The dam along with other downstream dams on the Missouri River comprises the "Pick Sloan Plan." This plan, authorized by the U. S. Congress in 1944, has succeeded in harnessing the Missouri River consequently protecting and benefiting the people in the entire basin.

The reservoir collects runoff from 57,725 sq. miles and stores a maximum of 19,100,000 acre-feet of water. As it is now used, the dam and reservoir provides flood control, silt control, power generation, river flow stabilization and minor amounts of irrigation water.

The Charles M. Russell Wildlife Refuge provides an abundance of water, food, and a natural habitat for: deer, elk, antelope, turkey, partridge, grouse, pheasants, ducks, geese and many other types of wildlife.

Numbers refer to footnotes located at the end of this chapter.

The fishing, camping, boating and other water related sports attract many visitors to the reservoir area. There are boat ramps at five locations, picnic tables at nine locations, camping areas at eight locations and many hiking areas connected with the dam and reservoir.

2. Tiber Dam and Reservoir.[2] The Tiber Dam is located on the Marias River in the southwestern portion of Liberty County. The reservoir backs up into the southeastern portion of Toole County. The drainage area served is approximately 5,000 square miles. The total capacity of the reservoir is 1,653,460 acre feet of which 285,302 acre feet are above the spillway elevation.

Although the dam was completed in 1956 for the purposes of irrigation, flood control, silt control and recreation, to date no distribution system for irrigation has been constructed. Its purpose to date has been primarily for municipal supply, flood and silt control and recreation. The dam and reservoir, by removing silt from the lower Marias River, has made that stream an excellent trout stream.

Six recreational areas are associated with the dam and reservoir. These areas have been developed cooperatively by the U.S.B.R. and the Montana Fish and Game Commission.

Tiber Dam and Reservoir is proposed to be improved and used in the Marias - Milk Unit as proposed by the U.S.B.R. This project is described in Part X of this report.

3. Fresno Dam and Reservoir.[3] The Fresno Dam and Reservoir is located in central Hill County. A total of 3,760 square miles drain to the dam, which has a usable capacity of 127,200 A.F. and a total capacity of 259,000 A.F. The dam and reservoir is multipurpose, serving as flood protection, irrigation, water supply and recreation. The dam construction was completed in 1939 and the reservoir has been primarily used for irrigation but with an available flood control capacity at the beginning of each spring runoff season. There is a fishery associated with Fresno Reservoir and fishing below the dam on the Milk River.

4. Nelson Reservoir and Dam.[4] The dam in eastern Phillips County was constructed in 1915. The reservoir is situated in a natural glacial depression with an earth fill dam at the outlet of the depression. Water is diverted in canals constructed by the U.S.B.R. to the reservoir from the Milk River below Fresno Dam.

The reservoir has a usable conservation storage capacity of approximately 67,000 A. F. The reservoir serves as a water supply for irrigation, and recreational purposes. Fishing is good in the reservoir and Sleeping Buffalo Recreation Area is associated with the dam and reservoir.

Cabins, camping, boating and fishing are all available either at or near the reservoir.

5. Milk River Irrigation Project.[5] The Milk River project is located in Glacier, Blaine, Phillips and Valley Counties, Montana. Water is diverted from the St. Mary River and stored in Sherburne Lake and then diverted through a 29-mile canal discharging into the North Fork of the Milk River. It then flows through Canada for 216 miles before returning to the United States. Milk River water is stored in Fresno Reservoir located 17 miles west of Havre, Montana, and in Nelson Reservoir, located 19 miles northeast of Malta. The water is diverted from the Milk River near Chinook and Harlem into private canals on each side of the river for land in that area, comprising the Chinook Division. Near Dodson, the Dodson North and the Dodson South canals of the Malta Division divert water for irrigation of land in the vicinity of Dodson, Wagner, Malta and Bowdoin. The Dodson South Canal conveys water for irrigation of land on the Malta Division south of the Milk River and also conveys water for storage in the Nelson Reservoir. From this storage, land is irrigated on the south side of the Milk River and Beaver Creek near Saco and Hinsdale. At the Vandalia Diversion Dam, the Vandalia South Canal follows along the south side of the Milk River, and carries water for irrigation of land near Tampico, Glasgow and Nashua which comprises the Glasgow Division. Land is also irrigated above the level of the gravity system along the Milk River Valley. This is accomplished by the Dodson Pumping Unit which elevates water from the Dodson North canal to irrigate additional lands above the gravity system.

When the Reclamation Service was established in 1902, the Milk River Project was investigated and this resulted in authorization of the project by the Secretary of the Interior on March 4, 1903.

The St. Mary Storage Unit was authorized by the Secretary of Interior on March 25, 1905, and construction begun on July 27, 1906. The treaty with Great Britain relating to the distribution between Canada and the United States of the waters of the St. Mary and Milk Rivers was signed on January 11, 1909. The Dodson Diversion Dam was completed in January of 1910 and the first water delivered for irrigation in the season of 1911.

Dams were completed on Sherburne Lake, Nelson Reservoir, St. Mary River, and Swift Current Creek in 1915, Vandalia Dam in 1921, and Fresno Dam in 1939. Fresno Dam and Reservoir,

formerly called Chain Lakes Dam and Reservoir, was constructed under the National Industrial Recovery Act and approved by the President in August 1955 pursuant to the acts of June 25, 1910 and December 5, 1924.

The Dodson Pumping Unit was approved by the President on March 17, 1944, and under the Water Conservation Act of August 11, 1939, the project was constructed to furnish water for about 1,655 acres of land above the gravity system.

A total of nearly 100,000 acres of land is presently being irrigated from the Milk River project. The operation of all storage facilities is by the Bureau of Reclamation with funds advanced by the water users.

C. EXISTING GROUND WATER DEVELOPMENT

Appropriated water wells and springs are registered and recorded with the Montana Bureau of Mines and Geology. Table VII-1 entitled "Water Well Inventory" and Table VII-2 entitled "Spring Inventory" show the total number of wells and springs as recorded in 1969 and their primary use for each of the nine counties. The tables also show the total number of wells and springs that were recorded in 1940. The figures show that the entire Study Area has a total of 5,853 wells and 1,547 springs and these numbers have more than doubled over the past thirty years. This would indicate that a ground water supply now exists in one out of every four square miles. This low density can be mainly attributed to poor water quality.

The Montana Water Resources Board has made an inventory of seven counties in the Study Area - namely, Glacier, Toole, Liberty, Hill, Blaine, Phillips, and Valley. Based upon the inventory, the average annual well appropriation was 13 Acre Feet. From discussions with geologists, and people living in the Study Area, it would appear that the appropriations are far in excess of actual pumpages.

Present usage of ground water is primarily for livestock and domestic needs, with only limited uses for industrial requirements. Due to inferior quality of available ground water in many localities, better-quality water is desirable for municipal use and preferred for domestic use, and will continue to be imported where possible. The principle industrial use of ground water, particularly in the western portion of the Study Area, is for the secondary recovery of oil. Almost all of the ground water presently withdrawn for industrial use comes from the deeper, more extensive aquifer formations, such as the Madison limestone.

TABLE VII-1

WATER WELL INVENTORY

	COMMERCIAL	FIRE PROTECTION	DOMESTIC	IRRIGATION	INDUSTRIAL	PUBLIC SUPPLY	STOCK	DOMESTIC & STOCK	INSTITUTIONAL	UNUSED	UNKNOWN	TOTAL
BLAINE	1		70	9	2	3	271	170	9	2	12	549
CHOUTEAU	2	1	129	11		20	303	347		6	7	826
GLACIER	10		114	10	25	10	80	156		2	9	416
HILL	7		336	17	9	13	209	223	5	11	16	846
LIBERTY			94	2		4	109	86		4	2	301
PHILLIPS	1		198	14	2	13	456	407	1	6	2	1100
PONDERA			43	3		14	75	148	1	2	1	287
TOOLE	1		34	6	12	15	139	109	1		1	318
VALLEY	8		273	21	4	32	440	40	3	7	15	1210
TOTAL (1969)	30	1	1291	93	54	124	2082	2053	21	40	65	5853
TOTAL (1940)	8		396	27	5	30	622	1011	5	22	19	2145

TABLE VII-2

SPRING INVENTORY

	COMMERCIAL	FIRE PROTECTION	DOMESTIC	IRRIGATION	INDUSTRIAL	PUBLIC SUPPLY	STOCK	DOMESTIC & STOCK	INSTITUTIONAL	UNUSED	UNKNOWN	TOTAL
BLAINE							62	1			121	184
CHOUTEAU			1	10			143	17		2	147	320
GLACIER			4				96	13			66	179
HILL			8	7			55	5			28	103
LIBERTY			1	7			37	6			16	67
PHILLIPS	1		2				50	11			30	94
PONDERA				9		1	17	2			28	57
TOOLE			6	16		36	101	7		1	10	177
VALLEY				15			314	9			28	366
TOTAL (1969)	1		22	64		37	875	71		3	474	1547
TOTAL (1940			5	32		10	428	41			161	677

Spring water is utilized for domestic and livestock purposes. A few springs reportedly also supply water for small-scale irrigation. Spring water usually has a relatively low amount of total dissolved solids and is preferred for domestic use where available in sufficient and reliable quantity.

FOOTNOTES - PART VII

[1] Further information about the Fort Peck Project can be obtained from:

Area Engineer, Fort Peck, Montana 59223
or U. S. Army Engineer Division - Missouri River
P. O. Box 103, Downtown Station
Omaha, Nebraska 68101

[2] For further information, see "Lower Marias Unit Definite Plan Report," USBR, November 1949 and pages 19 thru 22 of reference VIII-10.

[3] Additional information on the Fresno Dam and Reservoir is available at the USBR office in Malta, Montana.

[4] Additional information on Nelson Reservoir is available at the USBR office in Malta, Montana.

[5] History and operation of the Milk River Unit is available in MWRB Survey Reports for Blaine, Phillips, and Valley Counties and at the Milk River Project office of the USBR in Malta, Montana.

PART VIII - BENEFIT-COST ANALYSIS

PART VIII

BENEFIT COST ANALYSIS

A. BENEFITS

1. General. The Northcentral Montana Conservancy District can be expected to provide benefits from irrigation, drainage and mosquito control, municipal and industrial water supply, fish and wildlife enhancement, recreation, flood and erosion control, pollution control, and area redevelopment.

As discussed in Part V, the water requirements for irrigation are many times more than requirements for all other uses. For this reason, irrigation and irrigation benefits received the most attention during this preliminary survey of the proposed water conservancy district.

2. Irrigation Benefits. Benefits of irrigation development result from the increased production of agricultural and livestock products made possible by the application to the land of a regulated water supply, together with the more intensive use of labor and capital. Only those benefits which are of a tangible nature and are measurable in monetary terms are considered. These tangible irrigation benefits are termed direct, indirect, and public benefits.

It is indeed a difficult problem to estimate the costs and the yields and returns per acre for various crops because of the multitude of factors which are associated with these costs and yields on individual ranch situations. There is little doubt but what empirical studies have revealed that costs do vary widely for the growing of such crops from farm to farm, and there is also a large amount of variance in yields in individual situations.

All of the data presented in this report is aimed at reflecting a normal or typical situation which could be expected under good, sound, prudent management on newly irrigated acres. There has been an attempt to make the costs and yields consistent with one another, and most of the material used is based upon published material of the Montana Extension Service.

It should be cautioned that the costs and yields are not meant to reflect the absolute top productivity which could be achieved under superior management. It could undoubtedly be assumed that the benefits from

these crops could and would be increased in certain instances where superior management was employed. All of the assumptions in this report assume good, sound management, but not superior management levels.

Direct irrigation benefits result from the increase in net farm income with the application of water and accrue directly to the water user. To measure direct irrigation benefits, future use of newly irrigated lands was estimated and predicted net farm income with irrigation was compared with present income from the lands under dryland farming. As discussed in the section on "Agricultural Economy," the primary impact of irrigation development would be directed at expansion of the red-meat industry. It is estimated that new irrigated lands would be used as follows:

Crop	% New Irrigated Lands
Irrigated Alfalfa	50
Irrigated Pasture	30
Small Feed Grains - Barley, Corn, Silage, etc.	20
	100%

Certainly some of the newly irrigated lands would go into specialized crops other than the ones described above. The assumption of 50-30-20 is simply meant to be an approximation as to the anticipated impact or use of newly irrigated lands. This could change considerably over time as the area would develop. This assumption should also be examined further in detail if a detailed feasibility study is to be conducted.

Based on anticipated land use, the direct benefits from irrigation of new lands for the Study Area have been estimated as follows:[1]

Numbers refer to footnotes located at the end of this chapter.

Alfalfa - assuming irrigated alfalfa replaces non-irrigated alfalfa:

Irrigated alfalfa:

Direct operating cost	$51.75/acre
Direct sale revenue	$100.00/acre
4 tons/acre @ $25.00/ton	
Direct Benefit	$48.25/acre

Non-Irrigated alfalfa:

Direct operating cost	$13.98/acre
Direct sale revenue	$25.00/acre
1 ton/acre @ $25.00/ton	
Direct Benefit	$11.02/acre

Net direct benefit per acre of irrigated alfalfa:

Direct benefit irrigated	$48.25/acre
Direct benefit non-irrigated	$11.02/acre
Net direct irrigation benefit	$37.23/acre

Pasture - assuming irrigated pasture replaces non-irrigated pasture:

Irrigated pasture:

Direct operating cost	$31.55/acre
Direct sale revenue	$40.00/acre
10 A.U.M./acre @ $4.00	
Direct Benefit	$ 8.45/acre

Non-irrigated pasture (range land):

Direct operating cost	nil
Direct sale revenue	$ .20
1/20 A.U.M./acre @ $4.00	
Direct Benefit	$ .20

Net direct benefit per acre of irrigated pasture:

Direct benefit irrigated	$ 8.45/acre
Direct benefit non-irrigated	$ .20
Net Direct Irrigation Benefit	$ 8.25/acre

Small feed grains - assuming equal amounts of barley and corn silage replaces spring wheat:

Irrigated feed barley:

Direct operating cost:	\$60.44
Direct Sale revenue	
80 bu./acre @ \$.80	\$64.00
Direct Benefit	\$ 3.56/acre

Irrigated corn silage:

Direct operating cost	\$103.99/acre
Direct sale revenue	
17.5 ton/acre @ \$7.00/ton	\$132.50/acre
Direct Benefit	\$ 28.51/acre

Non-Irrigated spring wheat:

Direct operating cost	\$ 20.00/acre
Direct sale revenue	
16* Bu/acre @ \$1.35	\$ 21.60/acre
Direct Benefit	\$ 1.60/acre

*Average yield in 9 county Study Area.

Net direct benefit per acre of irrigated small feed grains:

Direct benefit irrigated small grains	\$ 16.04/acre
Direct benefit non-irrigated spring wheat	\$ 1.60/acre
Net Direct Irrigation Benefit	\$ 14.44/acre

Average net direct benefit per irrigated acre attributable to crop production is:

$$.5 \times \$37.23 + .3 \times \$8.25 + .2 \times \$14.44 = \$23.97\text{/acre}$$

In addition to the direct benefits which result from the more intensive farming associated with irrigation, there will be direct tangible benefits associated with the increased capacity for livestock production. The livestock industry would be affected in two major ways:

1. More livestock could be raised per acre with the increased supply of hay, small grains, and irrigated pasture.

2. Some calves could be winter fed in the area and marketed the following year as fattened cattle under more favorable market conditions.

Because of the large number of variables involved, it is difficult to assign benefits to this increased livestock production. Actual returns depend on factors like how near to capacity the ranch currently is in livestock production as far as barns and handling facilities are concerned, debt status of the ranch, and type of livestock operation. For present purposes, a debt-free cow-calf ranch with 250 cows as studied in Montana State University Circular 1103 is considered. Based on this type of operation, it is estimated that the net livestock benefit due to irrigation would be $14.25 per irrigated acre.

The total direct benefits for purpose of this report are:

Crop benefits	$23.97/acre
Livestock benefits	$14.25/acre
Total Direct Benefits	$38.22 - Say $40/irrigated acre

Direct benefits from providing supplement water to presently irrigated lands has not been explicitly covered in this study. When water is available for supplemental irrigation, it is a bonus not considered in this preliminary study. An exception is the Marias-Milk Unit which does consider supplemental irrigation benefits. This information will be contained in the Marias-Milk project report which should be available in the near future.

Indirect irrigation benefits result from the increase in profits of all marketing and processing enterprises involved in handling the increased farm production between the farm and the final consumer. They accrue to wholesalers, retailers, and processors involved in handling the increased production of farm products and the increased purchases by farm operators. These benefits include increases in family livelihood and in accumulation of equity in the farm investment.

Public irrigation benefits result from the increase, or improvement, of new farm settlement opportunities, new investment opportunities, and stabilization of local, regional, and, to some extent, the national economy. Public benefits are estimates of the value of achieving national objectives other than those included in direct and indirect benefits. The enhancement of economic growth is considered as the principal public benefit.

Indirect and public benefits are generally lumped and reported by government agencies together with direct benefits in project reports. To evaluate these benefits, available reports for irrigation projects in the area were reviewed. The USBR expects indirect and public benefits equal to 53 percent of the direct irrigation benefits,[2] whereas the Fort Belknap Project anticipates 70 percent[3] and the Blackfeet Project estimates indirect and public benefits at 54 percent of the direct irrigation benefits.[4]

It appears that a reasonable estimate of total tangible irrigation benefits would be 1.5 times the direct irrigation benefits for purposes of this preliminary study. With a direct irrigation benefit of $40/acre, the total irrigation benefit for the Study Area would be $60/acre.

There are many benefits of a real and significant nature, as concerns the general welfare, which are not measurable in monetary terms. These intangible benefits would include the improved local level of living, improved community facilities and services from an expanded tax base, greater local employment opportunities, and improved economic opportunities for the talented young people so vital to the continued development of an area.

Perhaps the best way of illustrating the intangible economic impacts which irrigation development can have on an area is to look at the experiences of similar areas following irrigation development. The Bureau of Reclamation, in a report covering the occasion of the 50-year anniversary of the Belle Fourche Project in South Dakota, pointed out the following:[5]

1. The population decline common to many agricultural communities did not occur in the project area.

2. Retail sales per capita in the irrigated area are double those in the adjacent dryfarm area.

3. Based on conveniences such as electricity and telephones, the level of living in the project area is 75% above the average for United States rural areas.

4. The project county had 87% more hospital bed capacity per 1,000 inhabitants and 67% more doctors and dentists than surrounding counties.

5. About 8,000 visitor days of water-based recreation took place on the project reservoir annually.

The products of a region are its trading stock. When range land and dryland are converted to irrigation, the gross product is increased many times. USBR project studies have shown that on the Lower Yellowstone Project which is located on the Montana-North Dakota State Line, the increase was 6 times.[6] On the North Platte Project, crop production was increased 13 times.[7] In New Mexico, on the Tucumcari Project, the increase was 64 times, because of the non-productive state of the pre-project agriculture.[8] It is safe to conclude that irrigation has raised agricultural productivity several fold in the west. But this is important chiefly in respect to the economic

impacts that were occasioned by it.

Studies made on the Columbia River Project in eastern Washington revealed that every dollar of net income in agriculture occasioned off-farm income of $1.50[9] The ratio of non-farm-to-farm income therefore was 1.5. An adjacent dryfarm area was similarly analyzed and the non-farm-to-farm ratio was 0.47 to 1. The contrast in the ratios for irrigated and dry-farm areas is due to the greater need for local processing and handling activities connected with intensive crops and fattened cattle produced in the irrigated area than for wheat and range cattle produced under dry conditions.

Experiences with the Yuma and Gila projects in Arizona, the Newlands Project in Nevada, the Grand Valley Project in Colorado, and studies in the Payette, Idaho, trade area and in Weld County, Colorado, as well as studies by Huffman at Montana State University and by the University of Nebraska lead to similar conclusions concerning the effect of irrigation development on the non-farm-to-farm income ratio.[10]

Based on numerous economic impact studies, for irrigation projects throughout the western United States, several of which are listed in the bibliography, the Bureau of Reclamation has concluded that 1000 acres of irrigated farm land adds $103,930 of gross farm production of crops and livestock products and adds payrolls of $106,799 in secondary jobs.

It goes without saying that irrigation development by itself does not automatically lead to gradiose economic improvements, but there is enough evidence to indicate that irrigation development can create an environment in which significant economic development is possible. It should also be pointed out that the economic and social impacts stated above are largely intangible and as such are unaccounted for in conventional benefit-cost evaluations. These impacts, when they occur, are bonuses over and above the economic returns which are present in an economically feasible project.

3. Drainage and Mosquito Control. The Study Area, particularly the Milk River Valley, has a serious mosquito problem. Aside from the obvious discomforts and health hazards (mosquitos infected with encephalitis have been found in the area) associated with mosquitos, there are also some very real economic losses. It has been estimated by various sources that mosquitos account for from 25 to 30 pounds of weight loss per animal per year to cattle in the area. Stories are told of cattle being huddled in a corner of the pasture and taking out entire fences in an attempt to escape the mosquitos. Considering the 508,000 or so

cattle in the area, it is easy to see how mosquitos can cost the area 3 to 4 million dollars annually in livestock losses alone.

4. Municipal-Industrial Benefits. Municipal and industrial water benefits are commonly based on the cost of the least costly single-purpose alternative for providing the necessary water supply. In the case of the Marias-Milk Project, estimated municipal and industrial water benefits of $31.00 per acre-foot were used by the USBR in determining the annual benefits, based on costs derived for the existing water system for the Town of Big Sandy. The project development plan provides for furnishing Big Sandy about 500 acre-feet annually.

5. Fish and Wildlife Benefits. The conservation and enhancement of fish and wildlife resources has assumed greater importance each year as the population grows and more leisure time becomes available. In determining fish and wildlife benefits, only those benefits that can be expressed in monetary terms are considered. The major benefits, particularly with respect to big game and waterfowl, would lie in the area of esthetics, enhancement of the quality of the environment, andin the perpetuation of high-plains game herds and endangered species. No way has been found to place monetary values on these benefits. The Bureau of Sport Fisheries and Wildlife should be consulted in the planning of multi-purpose water resources projects so that they can be provided for to the maximum extent practicable.

The economic portion of fish and wildlife benefits are often based on a schedule of values per recreational day of fishing and hunting. In the case of wildlife refuges, benefits are measured by the cost of the most economical alternative.

Annual fish and wildlife benefits for the Marias-Milk Project were estimated by the Bureau of Sport Fisheries and Wildlife to be $132,900, which would include $2,500 for enhancement of sport fishing in the Milk River below Fresno Dam, $16,500 for wildlife benefits on project lands, and $113,900 associated with development of new waterfowl nesting and resting areas along with providing additional water to Lake Bowdoin.[11]

Tangible fish and wildlife benefits attributable to the Corps of Engineers proposal for development of the Missouri River between Fort Peck Reservoir and Fort Benton, Montana have been estimated at $1,885,000 annually by the Fish and Wildlife Service. This figure includes benefits associated with the Fort Hawley Project, which, according to Mr. John Foster at the Bowdoin Wildlife Refuge has been abandoned, at least temporarily, in favor of the smaller U-L Bend Project. This project is similar to the Fort Hawley proposal but includes only about 1/4 of the area included in the Fort Hawley project. Preliminary benefit estimates for the U-L Bend Project place the annual value at $197,000.[12]

6. <u>Recreation Benefits.</u> Recreation benefits have generally been based on the estimated annual visitor-day usage and a unit value of $1.50 per visitor-day.[13]

Estimates of recreation usage of facilities associated with the Corps of Engineers proposal for development of the Missouri River between Fort Peck Reservoir and Fort Benton are placed at 540,000 visitor-days annually. This estimate of usage is the average of the maximum and minimum estimates prepared by members of a task group representing the Corps of Engineers, Bureau of Reclamation, National Park Service, Bureau of Sport Fisheries and Wildlife, and Bureau of Land Management.

It is estimated that the Marias-Milk Unit will not appreciably increase or decrease usage of the existing Tiber Reservoir. No recreational benefits have been considered in the economic evaluation of this project.

7. <u>Flood Control Benefits.</u> Flood control benefits are determined by estimating the damages that would occur with floods of various frequencies. Where possible, actual damages associated with recent floods are used. From this data, a damage frequency curve can be constructed and the average annual damage determined therefrom. Generally, estimates of flood control benefits are made by the Corps of Engineers because of their experience in this area. Wherever possible, flood control benefits as estimated by the Corps of Engineers were used in the model.[14]

The Corps of Engineers proposal for developing High Cow Creek and Fort Benton dams on the Missouri River would permit the replacement of flood control storage presently allocated to the Garrison Reservoir. This would permit additional benefits to be produced by that project by operating at a high pool level. The Corps of Engineers estimates the value of this replacement storage at $0.75 per acre-foot. The flood control storage available on a seasonal basis would be 100,000 acre-feet at the Fort Benton Reservoir and 400,000 acre-feet at the Cow Creek Reservoir, the resulting benefit being about $375,000 annually.

Modification to existing Tiber Reservoir would result in total long-term flood control benefits of $331,500 annually, according to estimates by the Corps of Engineers. Of this amount, $69,000 represents local flood control benefits now being obtained, and $262,500 represents flood control benefits that would be restored with completion of the Marias-Milk Project.

Other flood control projects in the Study Area which have progressed to a point where benefits can be estimated are the City of Shelby Watershed Project in Toole County, the Beaver Creek Project in Hill County, and the City of Browning Watershed Project in Glacier County. Average annual flood control benefits for these projects are \$81,661, \$18,975 and \$23,400 respectively.[15]

8. Other Benefits. Other benefits which should be considered for multi-purpose projects in the Study Area include pollution control, erosion control, and drainage. These benefits are difficult to evaluate during the preliminary stage and are generally local and secondary in importance. These benefits have not been evaluated in this preliminary report.

B. COSTS

1. Construction Costs. For this preliminary survey, detailed cost estimates reported for the various proposed projects were used whenever they were available. All costs were adjusted to January 1970 price levels using a cost index computed as the average of the USBR earth dam index and the composite irrigation and hydro cost index. See Figure VIII-1. Cost indices prior to 1940 when the earth dams and composite indexes were introduced were based on the Engineering News Record Construction Cost Index.

Construction costs for those projects for which no estimates were available were determined from an average reservoir cost versus capacity curve. This curve was developed from existing reservoir projects in and around the Study Area for which actual construction costs were available. Projects by the Montana Water Resources Board, Bureau of Reclamation, Corps of Engineers, Soil Conservation Service, and Bureau of Land Management were considered. Costs were adjusted to 1970 prices as described above, and a least squares fit of this data is shown in Figure VIII-2. Because there is a significant spread of the data, two additional curves are shown. One, termed the high cost curve, is intended to represent projects where foundation conditions are particularly unfavorable, associated works such as canals and diversions are extensive, or topography is such that a relatively large dam is required per unit volume of storage.

The second or low cost curve is intended to represent conditions opposite of those for the high cost curve.

While most dams can be reasonably represented by one of these three curves, the results for any particular project are preliminary only.

Costs of canals are based on actual construction costs of various size canals in areas of similar topographic and soils conditions.

COST INDEX FOR EARTH DAM
PROJECTS IN WESTERN
UNITED STATES

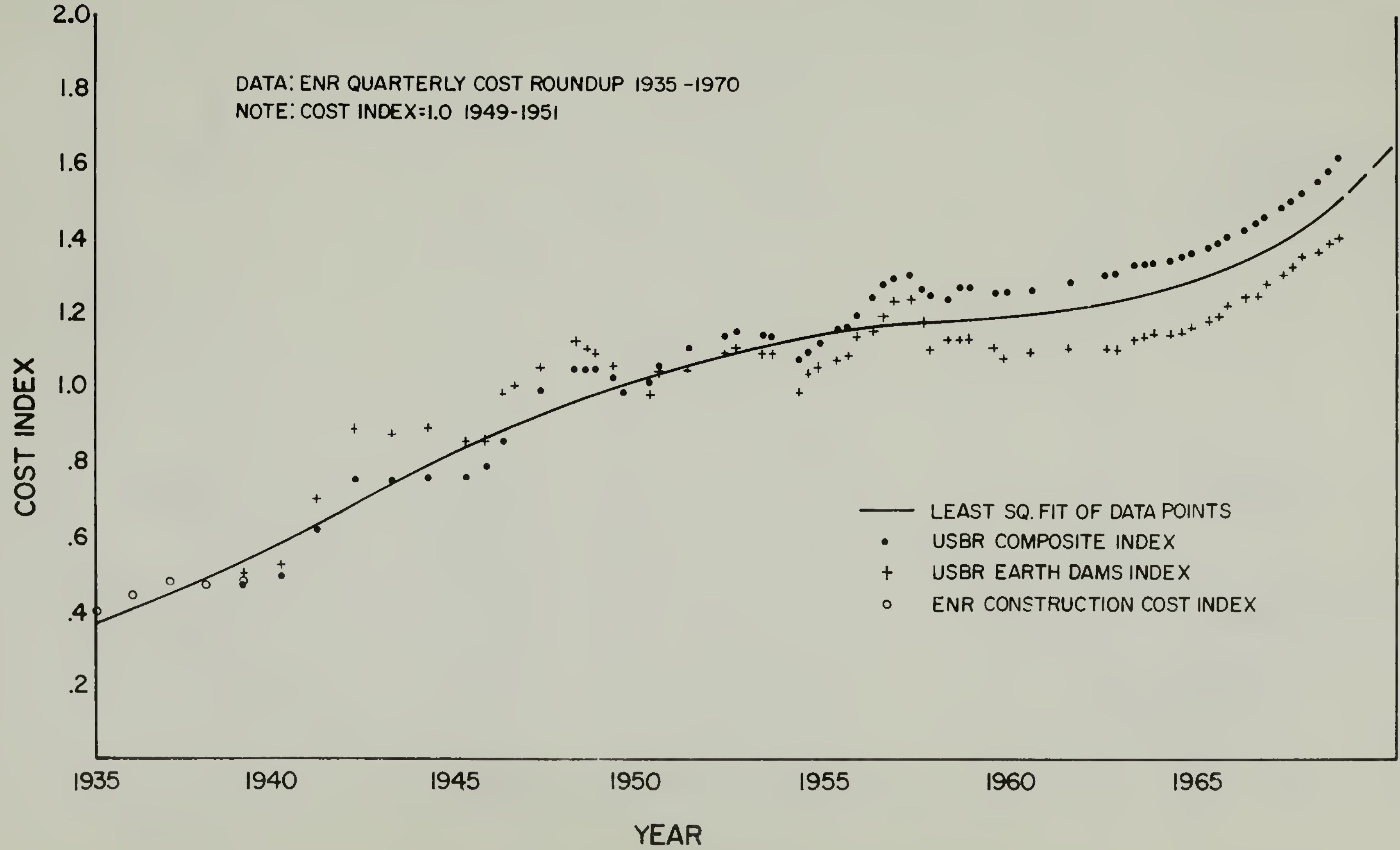


FIGURE VIII - 1

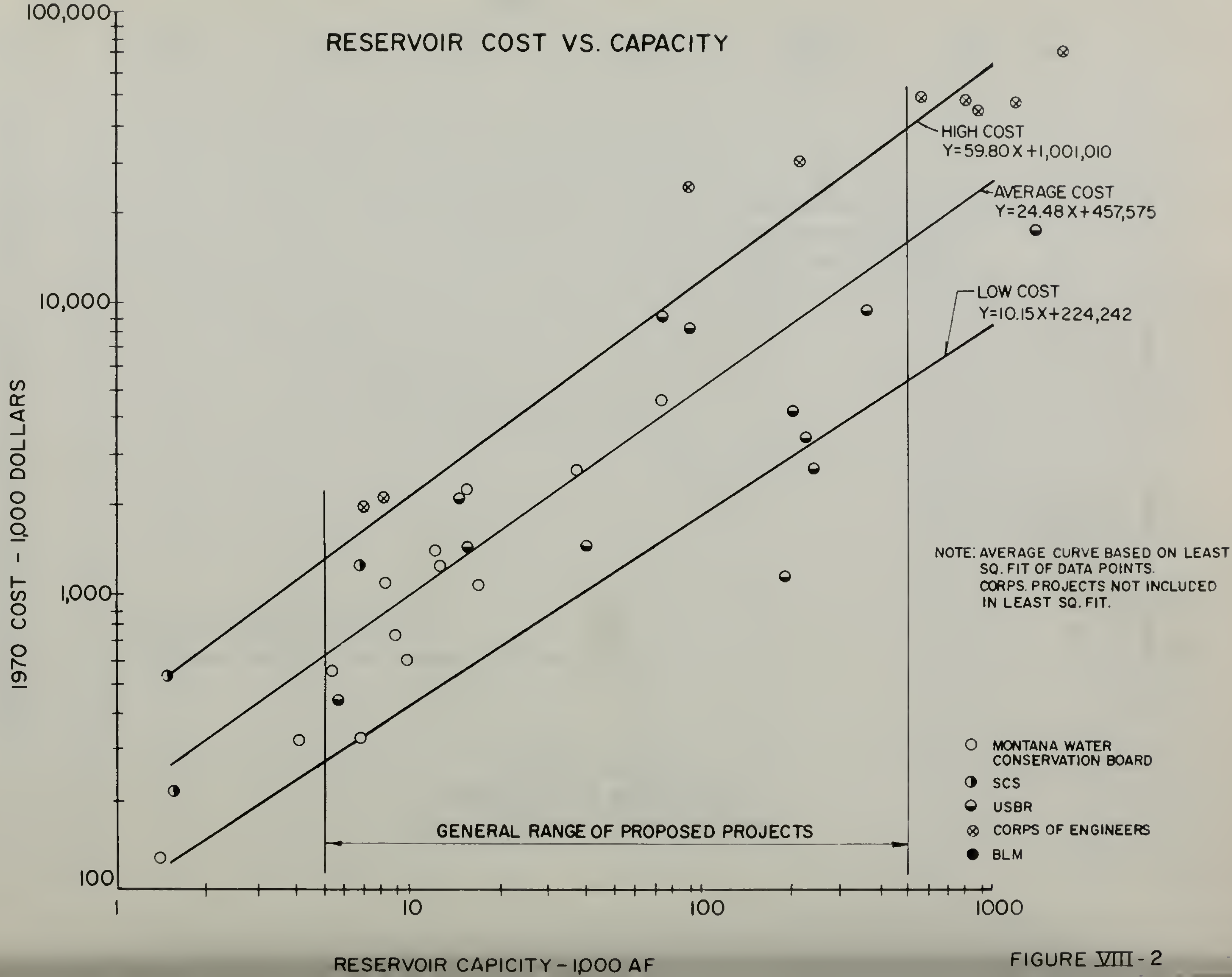


FIGURE VIII - 2

2. Operation, Maintenance and Replacement Costs. OM&R, like construction costs, were taken directly from project reports whenever possible. These costs were adjusted to 1970 prices using the cost index curve, Figure VIII-1.

To include the effect of operation, maintenance and replacement costs in proposed projects for which no information was available, OM&R costs amounting to 10% of the annual equivalent cost of construction were assumed. This assumption is consistent with the available information on projects of the general size and function as the proposed projects.

3. Total Annual Equivalent Cost. Total annual equivalent cost is based on the construction cost including interest during construction amortized over a 100-year period at an assumed interest rate of 5 1/8%, plus the annual OM&R costs.

Interest during construction cost was included in the construction costs and thus are not considered separately.

C. BENEFIT COST ANALYSIS

According to the economic efficiency concept, feasibility of a proposed project is determined by comparing benefits with costs. According to this concept a dollar value is assigned to every cost and benefit effect and if benefits outweigh costs, the project is said to be feasible. There is a growing recognition that this concept is deficient in that some cost and benefit effects have no market price. To fit in with the mathematical benefit-cost analysis, these effects must be given discretionary values. It follows that one man's judgment will likely be different from the next, so that the basic value inputs are inevitably subjective and cannot be more than indicative.[16]

It is not intended in this report to present detailed benefit-cost evaluations of proposed projects, but rather to indicate which projects appear to have the best chance of being economically feasible. Additional study will be required to reliably evaluate the feasibility of individual projects.

FOOTNOTES - PART VIII

[1] For backup information on expected yields and production costs, see Appendix F.

[2] Computed from preliminary cost-benefit data in draft of Marias-Milk Project Report.

[3] Based on primary and secondary benefits before adjustment for 10-year development period, pp. 44 and 45, reference no. VIII-8.

[4] Based on total project benefit summary p. 37, reference VIII-9.

[5] See page 415 of reference VIII-16.

[6] See page 6 of reference VIII-12.

[7] See page 413 of reference VIII-16.

[8] See page 2 of reference VIII-17.

[9] The results of the studies on the Columbia River Project are reported in reference VIII-15 and VIII-16 and also "Economic Development of the Columbia Basin Project Compared with a Neighboring Dryland Area," Washington State Cooperative Extension Service, January 1966.

[10] See reference VIII-16.

[11] "Marias-Milk Unit -- A Report on Fish and Wildlife Resources." This was included as part of the preliminary draft of the Marias-Milk Report, reference VIII-10.

[12] From "U-L Bend National Wildlife Refuge - Master Plan" and conversations with U. S. Department of the Interior, Fish & Wildlife Service personnel at the Bowdoin Refuge.

[13] See, for example, page 36 of reference X-1.

[14] For a list of Corps of Engineers flood control projects, see reference X-20.

[15] See page 25 of reference X-18, page 3 of reference X-1, and page 7 of reference X-19, respectively.

[16] See page 405 of reference VIII-16.

PART IX

APPLICATION OF OPTIMIZATION MODEL

PART IX

APPLICATION OF OPTIMIZATION MODEL

A. SYSTEMS ANALYSIS UNDERLYING THE PROBLEM

One of the specific objectives of this study is to identify the technical and economic optimality of alternative water resources system operating procedures and combinations of proposed facilities for performing various functions and meeting various needs within limited resources. In order to achieve this end, an appropriate systems analysis technique, linear programming, was applied to the North Central Montana Water Conservancy District.

To make the approach more understandable in the context of this report, some explicit answers are offered for the questions of "what", "why" and "when" as they relate to systems analysis in this report.

1. Systems Analysis Defined. Systems analysis is a mathematical modeling technique which may be employed as a decision aid in assessing the technical and economic consequences of alternative problem solutions. It is noted that systems analysis *per se* does not provide these assessments since ultimately the decision must also incorporate professional, legal, political, and social considerations.

2. Reasons for Using Systems Analysis. Systems analysis techniques have several advantages over traditional methods of design and analysis in the field of water resources management. Among them are:

a. All Aspects Included. Systems analysis makes it possible to provide a more effective union of engineering, economic and other decision-influencing considerations in the problem formulation and solution procedure;

b. Simulation of Uncertainty. With systems analysis, it is easy to provide a rapid means for incorporating considerations relating to risk and uncertainty in the problem solution;

c. Computational Consistency and Efficiency. Using systems analysis leads to an efficient computational procedure to explore in detail the interactions of large numbers of system components and the effect of these interactions on total system behavior by processing and organizing large amounts of information and data using computer technology.

3. Limitations of System Analysis. Perhaps the most severe constraint on the application of systems analysis to water resource problems relates to lack of reliable and meaningful data. Two types of limitations on the application of systems analysis are worth noting:

a. Data Limitation. Sufficient information must be available to determine values of coefficients, constants and facility capabilities as parameters which are needed to generate solutions to the mathematical model;

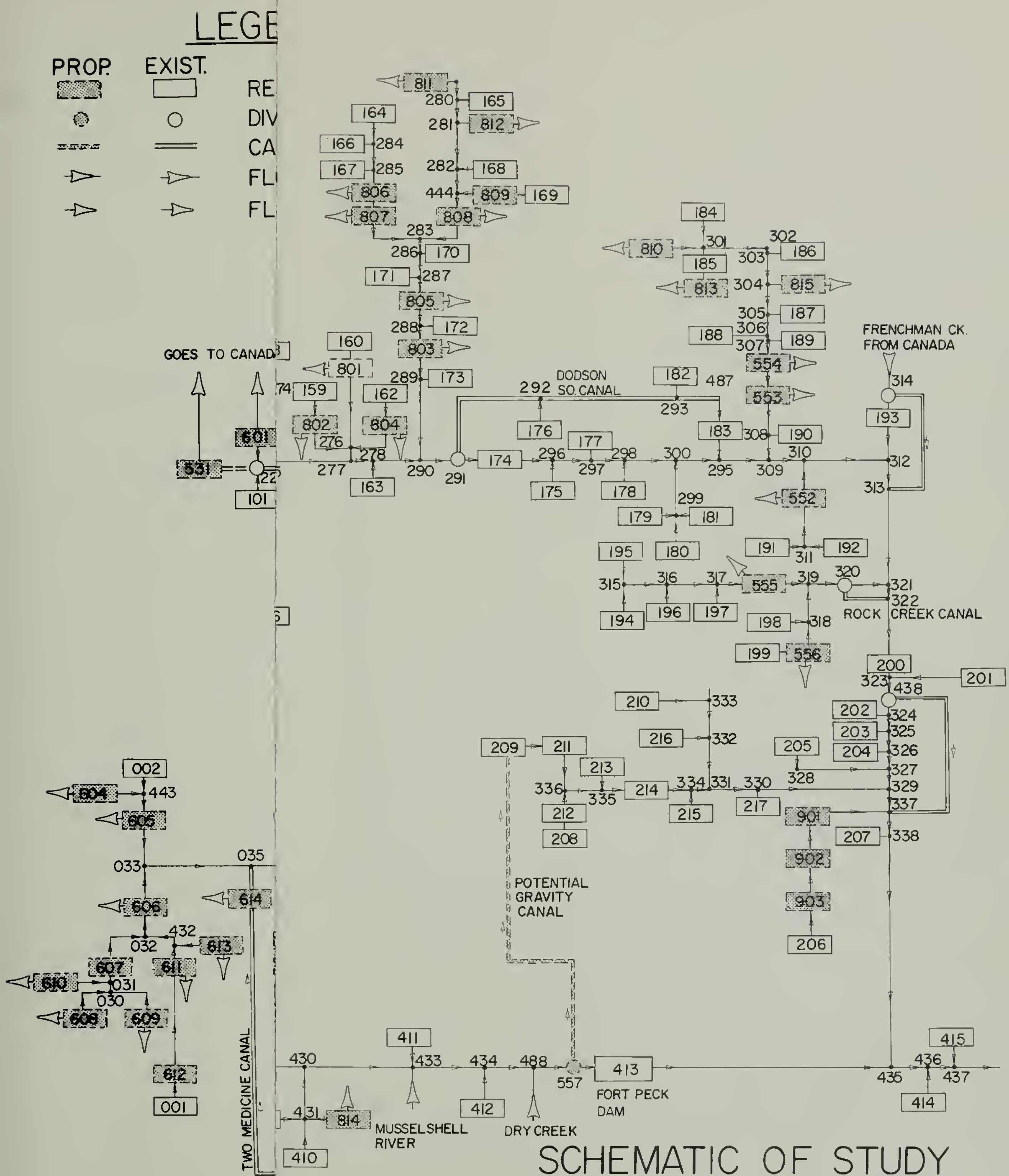
b. Conceptual Limitations. One must have sufficient insight into the structure of the system and the interrelationships between its components to represent accurately by means of a mathematical model the system being studied.

B. PROBLEM SOLUTION

The outline of the conservancy district problem solution presented herein follows Part B of Appendix A where a simplified sample problem is solved based upon the general linear programming optimization model information set forth in Part A of Appendix A. Raw input data for the problem appears in Appendix B while the CDC 6600 computer input and output data are supplied under separate cover from this report.

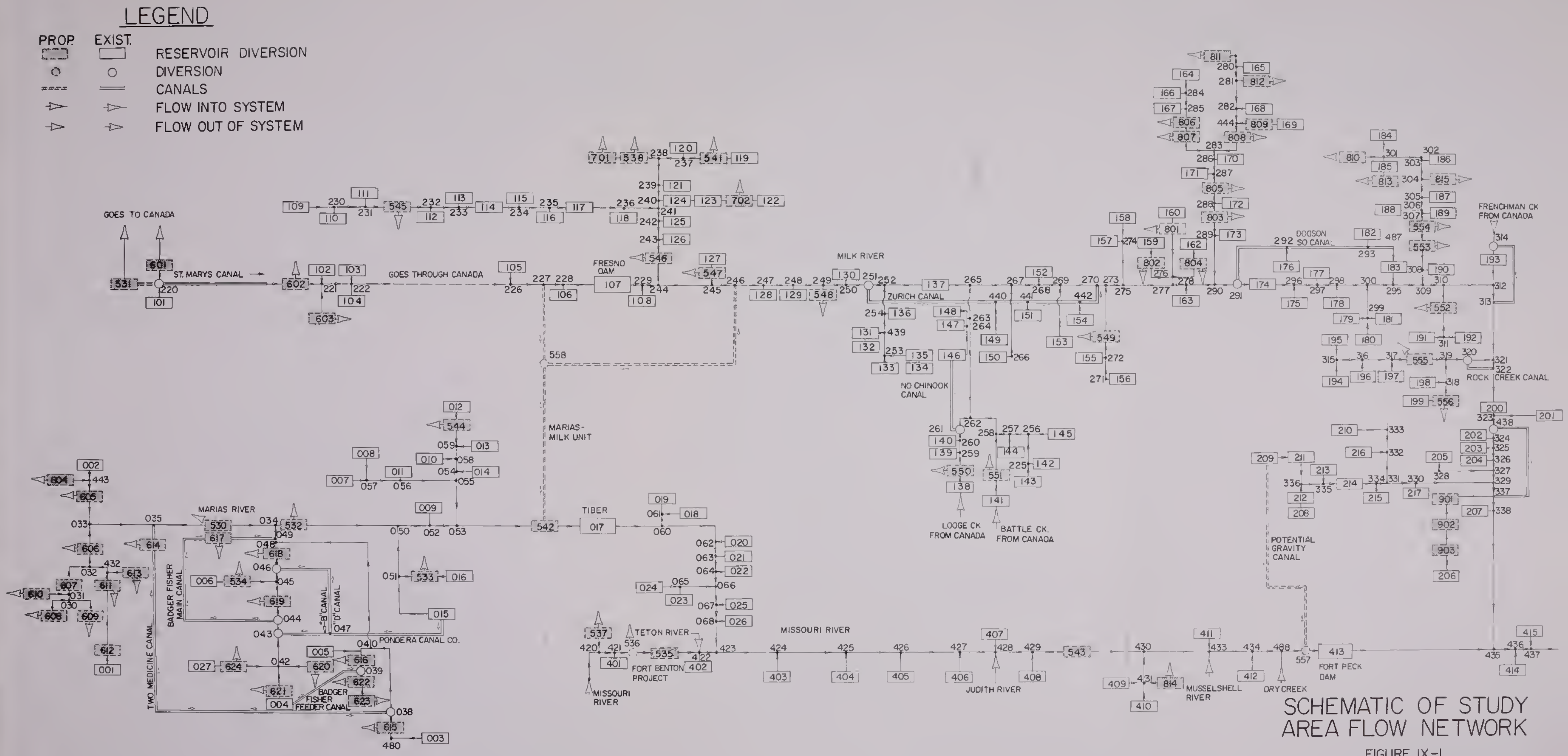
1. System Description. Figure IX-1 shows the schematic diagram of the conservancy district network in terms of the network symbols shown in Figure IX-2 (similar to Figure A-3 of Appendix A). Node identification numbers have been limited to 3 digits in order that the longest variable identification names referred to in Appendix A be limited to 8 characters.

2. Data Identification, Formulation of Objective Functions and Constraint Restrictions. In the optimization model, 2 seasons were used: A wet season (Season 1) ranging from October through April and a dry season (Season 2) ranging from May through September. Local inflows to the network which occur at various nodes were scaled down to 65% of their average annual values to simulate a low-flow condition which might occur in a typical dry year. When the problem was completely formulated 1,178 variables were identified along with 956 constraint relations. Obviously, for a problem this size, it is impossible to display the data in a table such as Table A-2 of Appendix A. Alternatively, Table B-1, Appendix B, gives the numerical raw data used in the model. This table contains the following 5 groups of system components: ordinary channel junctions, existing reservoirs, proposed combinations of reservoirs and diversions, existing diversions and proposed diversions. Two special constraints which were applied are not summarized in Table B-1. These constraints are stated as



SCHEMATIC OF STUDY AREA FLOW NETWORK

FIGURE IX-1



SCHEMATIC OF STUDY AREA FLOW NETWORK

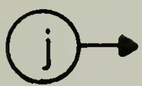
FIGURE IX-I

FIGURE IX - 2

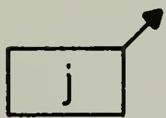
NETWORK SYMBOLS

j — Junction (no variables)

Existing Reservoir (Rtj variable) *



Existing Diversion (Dtj variable)

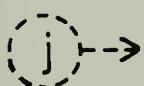


Existing Reservoir - Diversion (Rtj and Dtj variable)

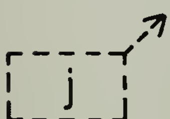
Existing Natural Branch (Qtjk variable)

Existing Man - made Branch or Canal (Qtjk variable)

Proposed Reservoir (Rtj and Sj variable)



Proposed Diversion (Dtj and Sj variable)



Proposed Reservoir - Diversion (Rtj, Dtj and Sj variable)

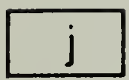
Proposed Branch or Canal (Qtjk and Sjk variable)

* *As the discussion in Part A of Appendix A has indicated, any variable item cited in this table can be fixed.*

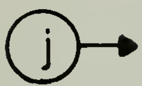
FIGURE IX-2

NETWORK SYMBOLS

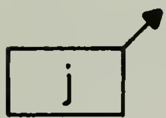
j — Junction (no variables)



Existing Reservoir (Rtj variable) *



Existing Diversion (Dtj variable)

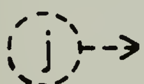


Existing Reservoir - Diversion (Rtj and Dtj variable)

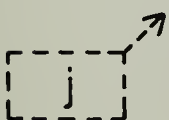
Existing Natural Branch (Qtjk variable)

Existing Man-made Branch or Canal (Qtjk variable)

Proposed Reservoir (Rtj and Sj variable)



Proposed Diversion (Dtj and Sj variable)



Proposed Reservoir - Diversion (Rtj, Dtj and Sj variable)

Proposed Branch or Canal (Qtjk and Sjk variable)

* *As the discussion in Part A of Appendix A has indicated, any variable item cited in this table can be fixed.*

follows: Yearly depletion of available water from Series 600 Indian projects in the Marias River basin (all Series 600 projects except 601, 602 and 603) equals 180,000 acre-feet: (133,000 A.F. additional plus 47,000 A.F. present depletion) and yearly depletion of available water from Series 800 Indian projects is no more than 108,600 acre-feet. In order to complete the operation of the optimization model, 3 objective functions were chosen:

a. Annual Benefit. The components of this objective function, which was maximized, are explained in Part A-3 of Appendix A under the description of its abbreviation, BOBJ.

b. Annual Cost. The components of this objective function, which was minimized, are explained in Part A-3 of Appendix A under the description of its abbreviation, COBJ.

c. Annual Net Benefit. This ojective function, the difference between BOBJ and COBJ, was maximized.

3. Model Input Data and Program Statements. The actual input data for the model appears in the computer printout supplied under separate cover. Program statements for the CDC OPHELIE program are the same as those shown in Figure A-7 for the simplified example problem in Part B of Appendix A with the exceptions that the problem name is HYDRO6, the bound set is BD1, and the right-hand side is RUN1.

4. Model Output Data. Actual model output data appears in the computer printout supplied under separate cover. Project selection results for the 69 proposed projects in the model appear in Table IX-1. The criterion for project selection for a given objective function is that the project size (indicated by the variable names beginning in S) be greater than zero. The net benefit objective function, NOBJ, was selected as the most representative of true project merits; results from the NOBJ solution form a basis for project selection in the functional plan of Part X, Summarized results from Table IX-1 are as follows:

a. Maximum BOBJ. 47 projects selected.

b. Minimum COBJ. 19 projects selected.

c. Maximum NOBJ. 44 projects selected.

Table IX-1

Conservancy District Proposed Project Selection

Item of Interest	Value at Max. BOBJ	Value at Min. COBJ	Values at Max. NOBJ
BOBJ[1]	(68,280.350)	63,410.430	68,246.920
COBJ[1]	26,222.880	(25,076.070)	26,077.970
NOBJ[1]	42,057.470	38,334.360	(42,168.950)
<u>Projects</u> [2]			
S530[2]	0	0	0
S532	0	0	0
S533	0	0	0
S534	0	0	0
S535	765[3]	765[3]	765[3]
S536	1.5	0	
S537	13.1	0	13.1
S538	0.08	0	0.08
S541	1.54	0	1.54
S542	573.6[3]	573.6[3]	573.6[3]
S543	875[3]	875[3]	875[3]
S544	0	0	0
S545	1.08	0	1.08
S546	5.22	0	5.22
S547	0.4	0	0.40
S548	1.14	0	1.14
S549	0.54	0	0.54
S550	8.37	0	8.37
S551	6.9	0	6.9
S552	2.62	0	2.62
S553	6.31	0	0
S554	0	0	4.35
S555	6.44	0	5.79
S556	2.93	0	3.58
S601	20[4]	0	20.[4]
S602	62.98	0	62.98
S603	65.52	0	65.52
S604	3.72	1.31	3.72
S605	0	2.25	0
S606	0	5.08	0
S607	2.03	0	5.35
S608	1.87	1.83	0
S609	3.51	0	0
S610	13.03	4.62	13.03
S611	13.60	4.33	13.60
S612	4.81	1.44	1.44

S613	19.38	6.87	19.38
S614	0	0	0
S615	0	1.26	0
S616	14.04	14.04	14.04
S617	0	2.62	2.62
S618	0	1.09	0
S619	75.03	38.44	76.05
S620	1.58	1.58	0
S621	1.58	0	1.58
S622	2.6	0.37	2.6
S623	10.31	0	8.08
S624	18.88	3.24	18.88
S701	0	0	0
S702	0	0	0
S801	0.5	0	0.5
S802	0.73	0	0.73
S803	4.4 4/	0	4.4 4/
S804	0.66	0	0.66
S805	7.06	0	4.78
S806	.83	0	3.11
S807	0	0	0
S808	0	0	0
S809	0	0	0
S810	0	0	0
S811	0	0	0
S812	0	0	0
S813	0	0	0
S814	4.33	0	4.33
S815	0	0	0
S901	1	0	1
S902	3.5	0	3.5
S903	3.4	0	3.4
S557209	30 4/	0	30 4/

1/ Capacity variables expressed in Units of 10^3 dollars (optimum appears in parentheses).

2/ Capacity variables expressed in volume units of 10^3 acre-feet.

3/ Fixed value.

4/ Operating at upper bound.

PART X - FUNCTIONAL PLAN OF DEVELOPMENT

X - FUNCTIONAL PLAN OF DEVELOPMENT

A. FORMULATION OF PLAN

This report has considered projects that have been proposed by various agencies and individuals to evaluate the most efficient, economical, and beneficial use of the available water. The complete list of proposed projects considered herein is tabulated in Appendix C. A preliminary screening of these projects was made based on the following criteria:

1. Average flow to structure was at least 2 cubic feet per second - an estimate of the amount required to irrigate a one-family-unit farm.

2. Project located where water could physically be delivered to areas needing additional water.

Projects which met these criteria were included in the optimization model described in Part IX of this report.

A common engineering practice in preliminary studies of this type is to base the availability of water on average annual flows. In this study (see Part VI) 65% of the average flow is assumed to be firmly available for irrigation and other development. This reduction was made to be reasonably conservative in the determination of water availability and to consider the effects of evaporation and losses and the cyclic distribution of the historic drought periods.

Within the Study Area, there are 415,000 acres presently under irrigation. Based on preliminary studies, there are approximately 2,774,000 more acres that are capable of supporting sustained irrigation by either sprinkler or gravity methods. When detailed soils, topographic and drainage influences have been considered, the total amount of potentially irrigable land will be reduced somewhat through refinement of individual irrigable areas. There is, however, much more irrigable land in the Study Area than there is water for irrigation development.

If 65% of the average annual stream flows are assumed to be firmly available for irrigation purposes then there is water available in the Study Area not presently being used. The water available exists in the following streams in the following amounts:

Stream	Available Water (65% of average annual flow)
1. Milk River	236,000 A. F.
2. Marias River	318,000 A. F.
3. Missouri River	90,000 A. F.
4. St. Mary River	27,000 A. F.
5. Waterton-Belly Rivers	156,000 A. F.
Total	827,000 A. F.

The water shown to be available in the Milk River has been reduced by 29,000 A. F. for the Canadian share of the Milk River flow not used at this time but expected to be used in the future, and an additional reduction of 75,000 A. F. allotted for minimum flow in the river to maintain water quality. The available water in the Marias River was reduced by 122,400 A. F. for water quality control.[1] Because only that small portion of Missouri River water which originates in the Study Area was considered as being available to the Study Area for development, no water quality deduction was made from this Missouri River contribution. The water quality requirements for the Milk and Marias Rivers were determined by the USBR as the release requirements from Tiber and Fresno reservoirs under the Milk-Marias Unit. When additional lands are irrigated, the total dissolved solids load on the streams would increase and additional water would have to be allotted to water quality control. This would be particularly true of the Milk River where much of the new irrigated land would be located. When the new lands have been definitely determined and the soils have been analyzed for soluble salt content, the minimum flow requirements can be more accurately determined.

The 27,000 A. F. flow shown to be available in the St. Mary River was computed by deducting the 149,400 A. F. average (1930-1964) U. S. diversion from St. Mary River to North Fork Milk River from 65 percent of the average annual U. S. share of the St. Mary River flow (271,000 A. F.). During an average year, this 27,000 A. F. (based on 65% supply year) would increase to 122,000 A. F.[2] that could be diverted to the Milk River under the present international agreement if sufficient storage and diversion facilities were available.

The Waterton-Belly water shown is 1/2 of the 65 percent average annual flow presently passing unused into Canada from the Waterton and Belly drainage systems.

The optimization model discussed in Part IX provides a useful analytic tool for evaluating the optimum combination of potential projects and determining the economic feasibility of individual projects and combination thereof. The project plan presented herein has been derived through consideration of the optimization model results, numerous independent project investigations, and discussion with local residents familiar with the needs and potentials of the area.

A list of projects that were selected by the optimization model is presented in Part IX. These projects are shown as solid red triangles on the irrigation maps. Selection of projects by the model constituted the primary criteria in the formulation of the functional plan.

The irrigation maps for the nine counties show:

Numbers refer to footnotes located at the end of this chapter

1. Existing irrigated land.

2. Potential irrigable land (Class 1, 2, or 3).

3. Existing storage projects.

4. Potential storage projects.

5. Potential storage projects included in the functional plan.

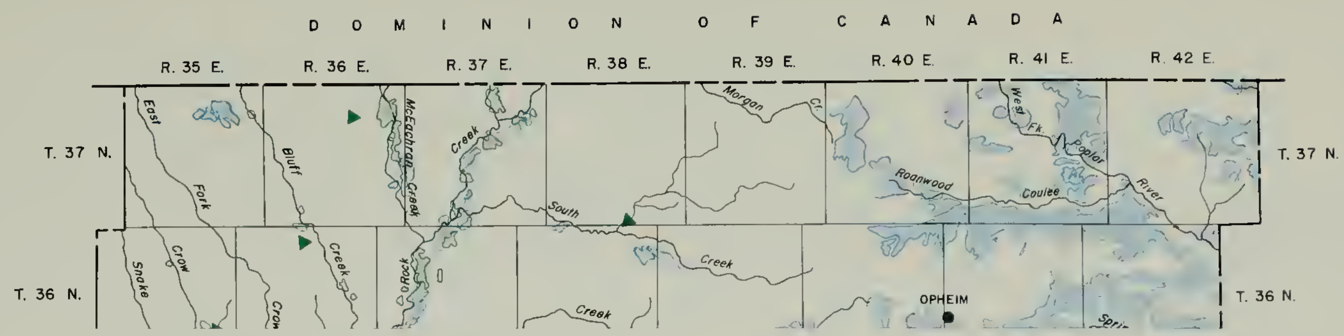
6. Land irrigated under the functional plan.

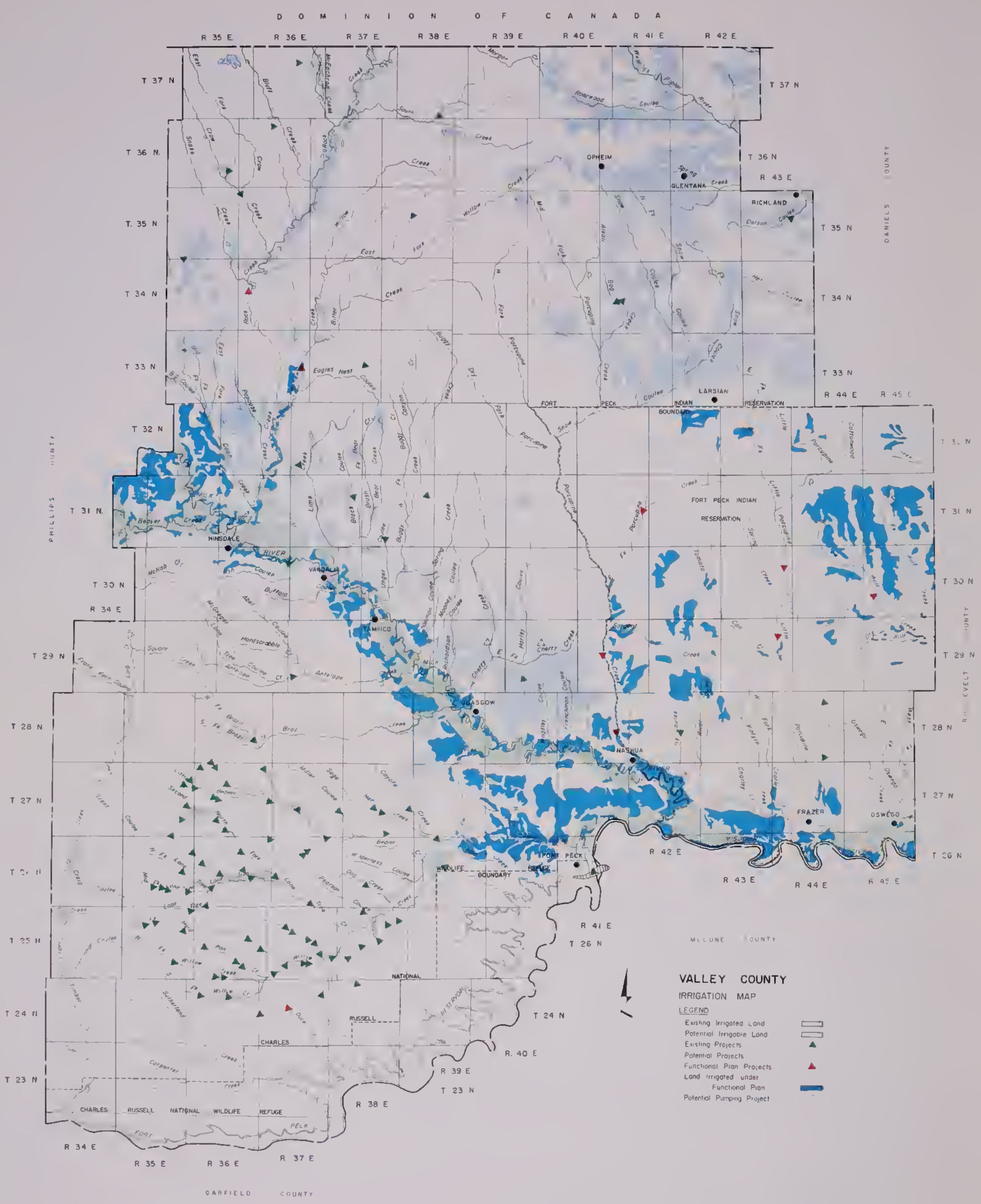
7. Potential large-scale pumping projects.

The land indicated as irrigated under the functional plan should be interpreted as land for which water could be made available with relative ease under the functional plan of development. It is not intended to imply that all of the area shown in solid blue would be developed for irrigation, nor that only those areas that are shown in solid blue will ever be considered for irrigation. The Upper Marias Area in Toole and Liberty Counties is a good example of this. A potential project by the USBR would provide water for irrigation of 69,000 acres in the Upper Marias Area, but which 69,000 acres of the Class 1, 2, or 3 lands that would be irrigated cannot be determined without a detailed study. For this reason, the potentially irrigable land in the Upper Marias Area is shown striped, rather than showing a particular 69,000 acres in solid blue. The irrigated lands under the functional plan do, however, show a preliminary attempt at matching irrigable land with available water supply for the entire Study Area.

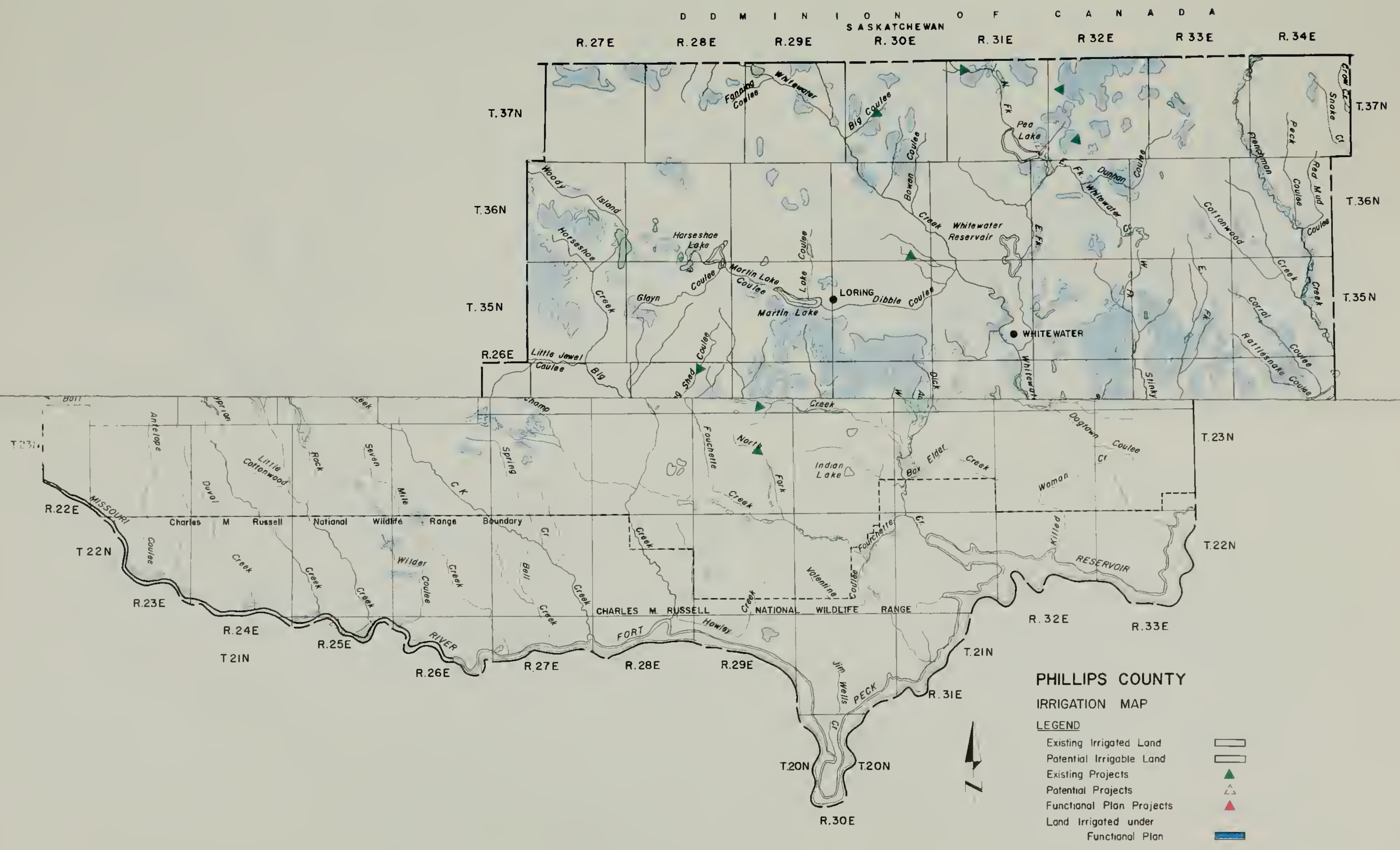
B. MAJOR ELEMENTS OF THE FUNCTIONAL PLAN

1. Additional Storage Sites on Milk River and Tributaries. The Milk River flows are not being fully used even during the design period when only 65% of average annual flow occurs in any one year. There are 340,000 acre-feet passing the gate at Nashua during this design year which would indicate that there is insufficient storage capacity on or along the river for flow regulation or the water is not being managed to the best advantage during periods when there are heavy demands on the water, or both. It seems reasonable that if more storage and regulation capacity were available along the Milk River, the flows that pass Nashua could be impounded and then supplied at a time when the water is needed. The important point here is that all of the irrigators along the Milk River could have more water when it is needed most - during the irrigation season - if additional storage were provided and if the water users pooled their collective water rights so that an effective water management program could be instituted for the benefit of all.

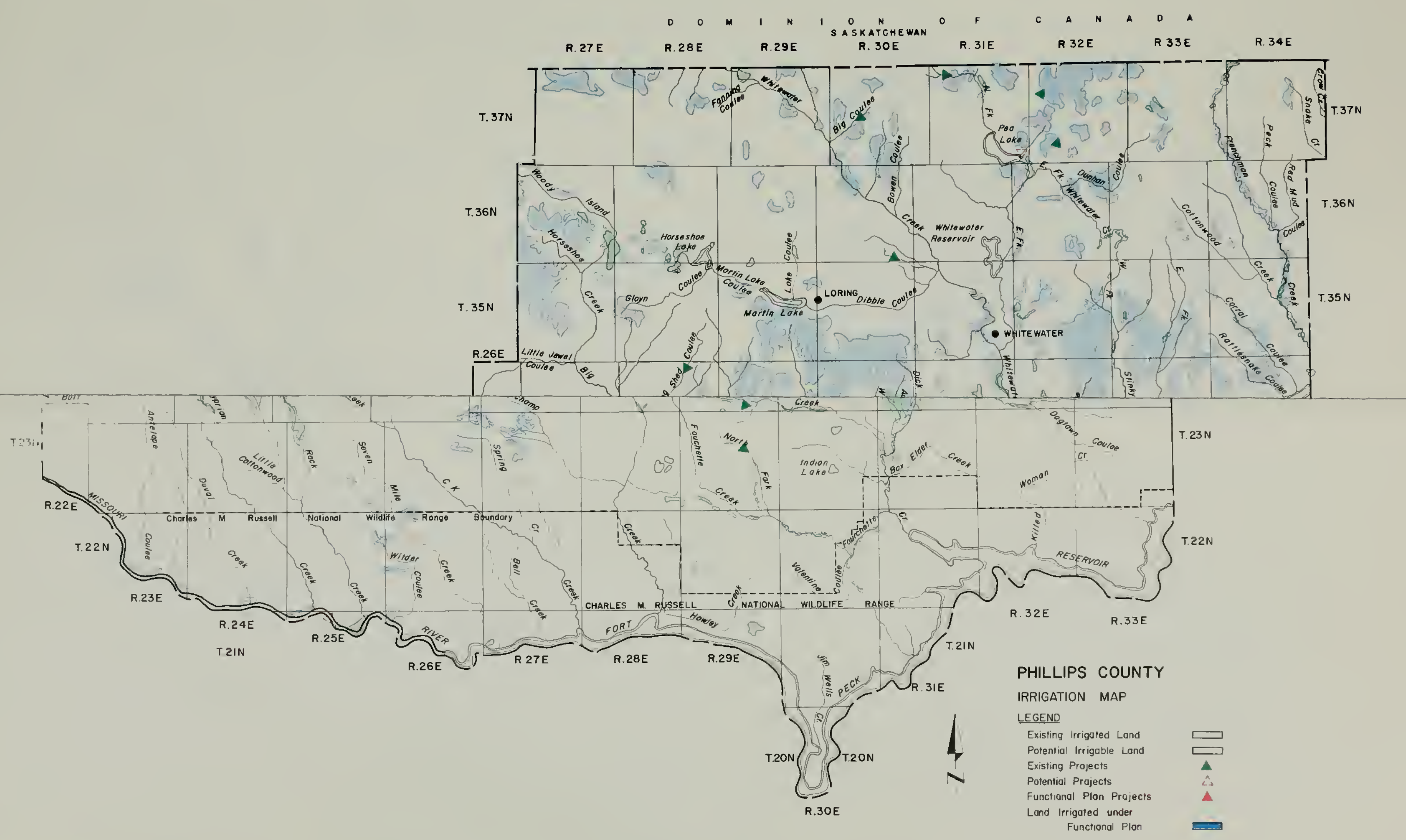

DOMINION OF CANADA
R. 35 E.
R. 36 E.
R. 37 E.
R. 38 E.
R. 39 E.
R. 40 E.
R. 41 E.
R. 42 E.
T. 37 N.
T. 36 N.
East Fork
Bluff Creek
McEachran Creek
Creek
South Creek
Morgan Cr.
Roanwood Coulee
West Fk. Poplar River
Snake
Crow
Rock
Creek
OPHEIM



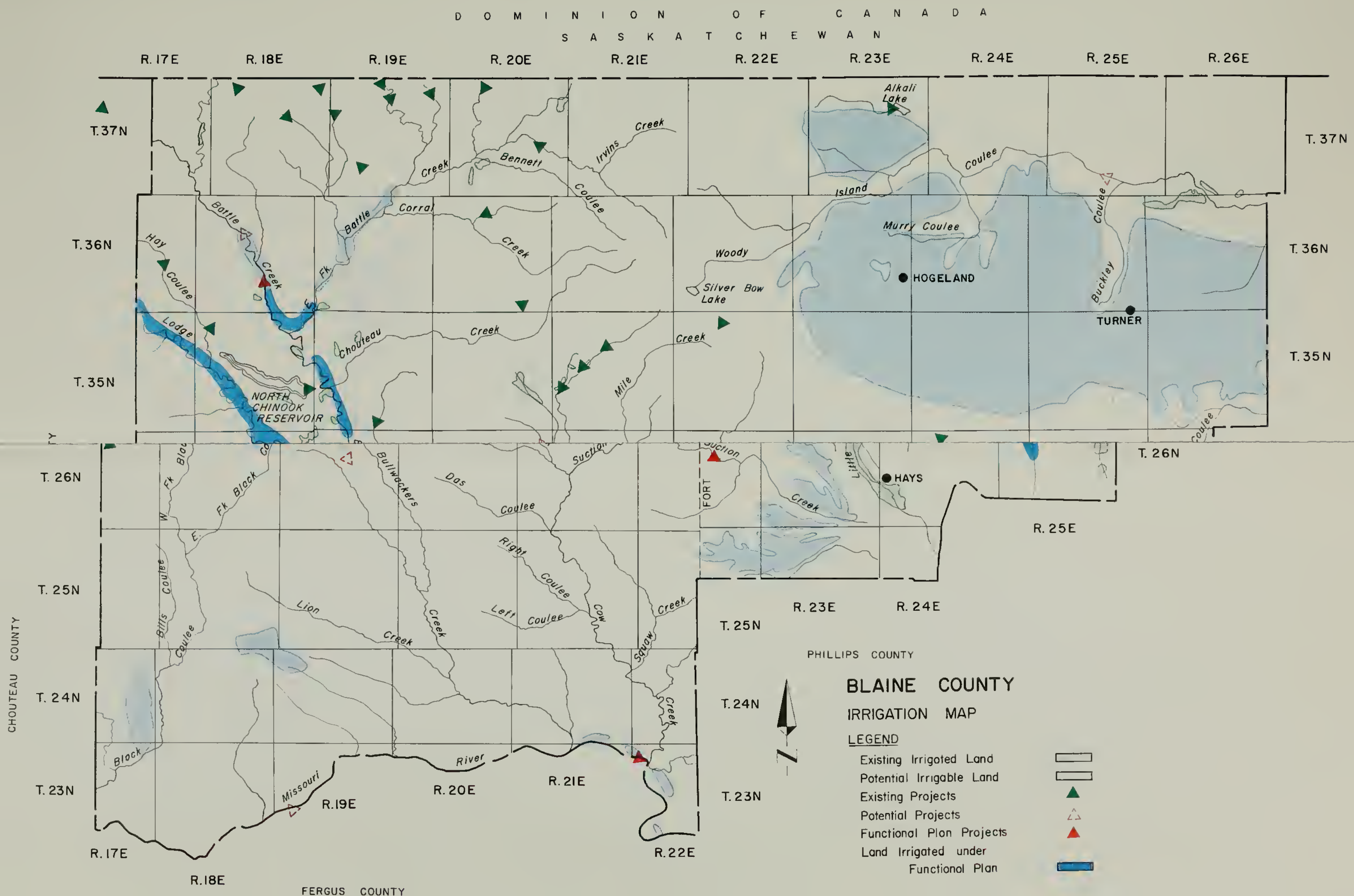
DOMINION OF CANADA
VALLEY COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Irrigated under Functional Plan
Potential Pumping Project
OPHEIM
GLENTANA
RICHLAND
LARSIAN
HINSDALE
VANDALIA
TAMPICO
GLASGOW
NASHUA
FRAZER
OSWEGO
FORT PECK
FORT PECK INDIAN RESERVATION
CHARLES RUSSELL NATIONAL WILDLIFE REFUGE
PHILLIPS COUNTY
DANIELS COUNTY
McCONE COUNTY
GARFIELD COUNTY



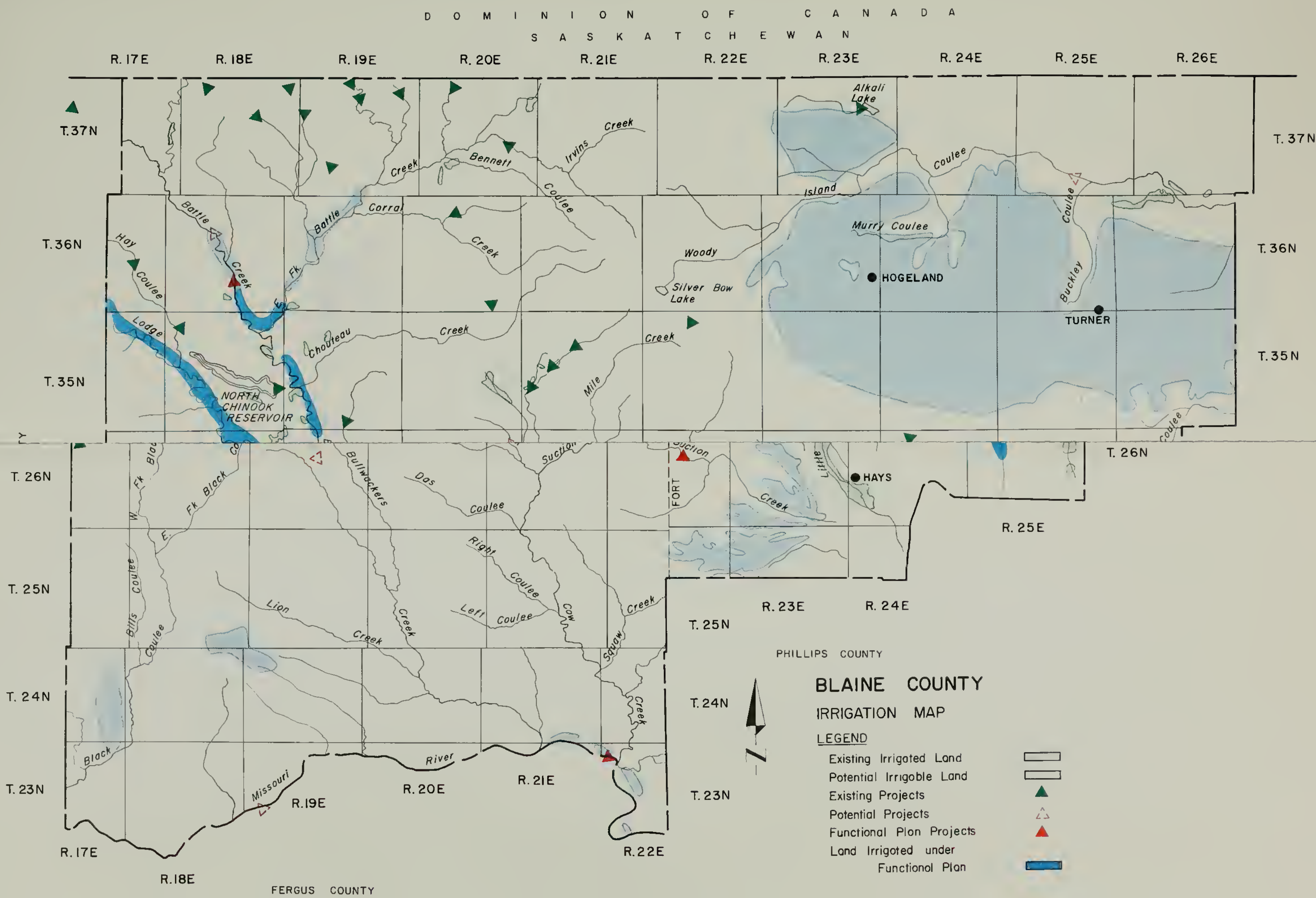
PHILLIPS COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Irrigated under Functional Plan
DOMINION OF CANADA
SASKATCHEWAN
R.27E
R.28E
R.29E
R.30E
R.31E
R.32E
R.33E
R.34E
R.26E
R.22E
R.23E
R.24E
R.25E
T.37N
T.36N
T.35N
T.23N
T.22N
T.21N
T.20N
LORING
WHITEWATER
Whitewater Reservoir
Martin Lake
Horseshoe Lake
Pea Lake
Indian Lake
CHARLES M. RUSSELL NATIONAL WILDLIFE RANGE
Charles M Russell National Wildlife Range Boundary
MISSOURI RIVER
FORT PECK RESERVOIR

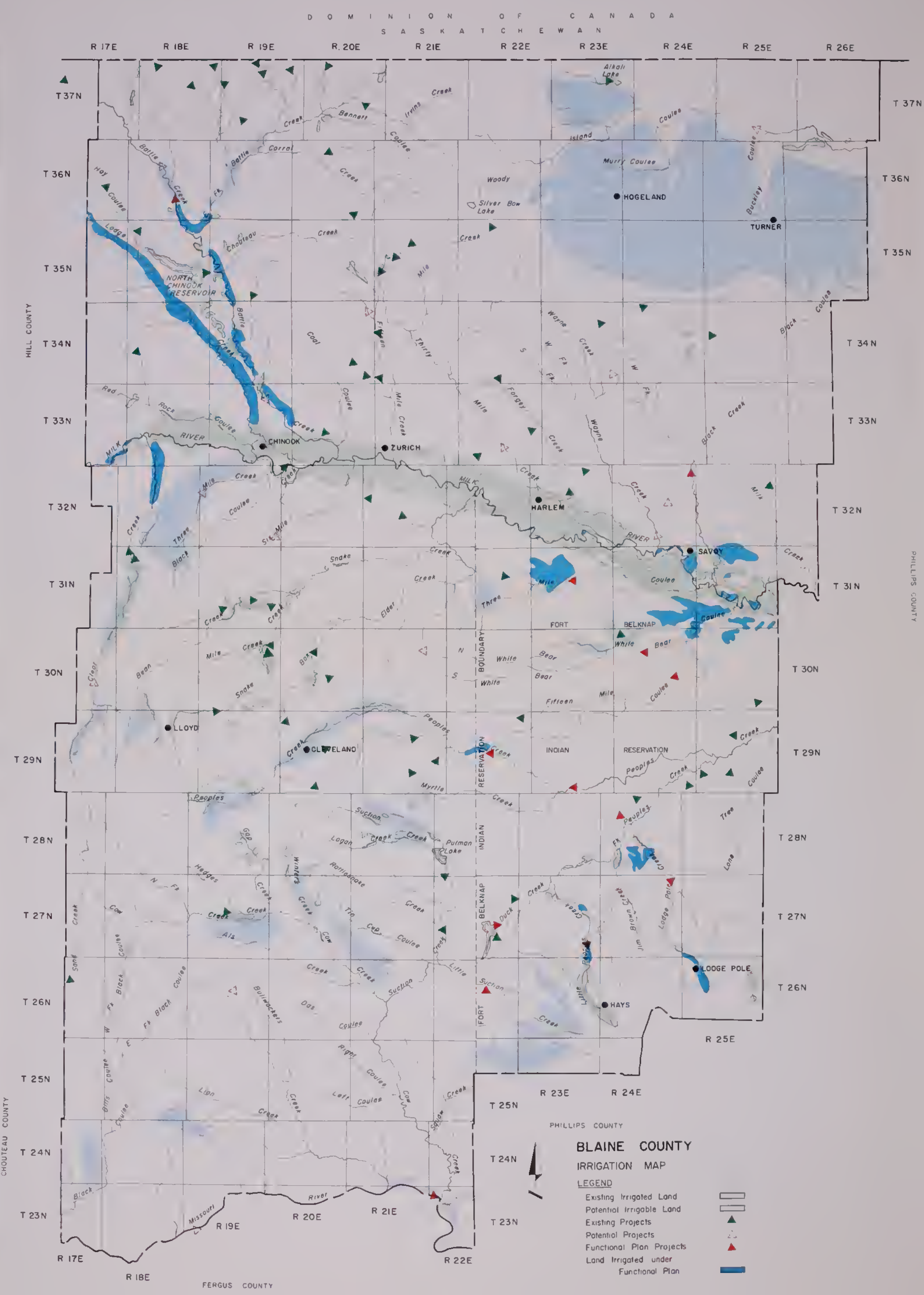

PHILLIPS COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Irrigated under Functional Plan
DOMINION OF CANADA
SASKATCHEWAN
LORING
WHITEWATER
Whitewater Reservoir
Martin Lake
Horseshoe Lake
Pea Lake
Indian Lake
CHARLES M. RUSSELL NATIONAL WILDLIFE RANGE
Charles M Russell National Wildlife Range Boundary
FORT PECK RESERVOIR
MISSOURI RIVER

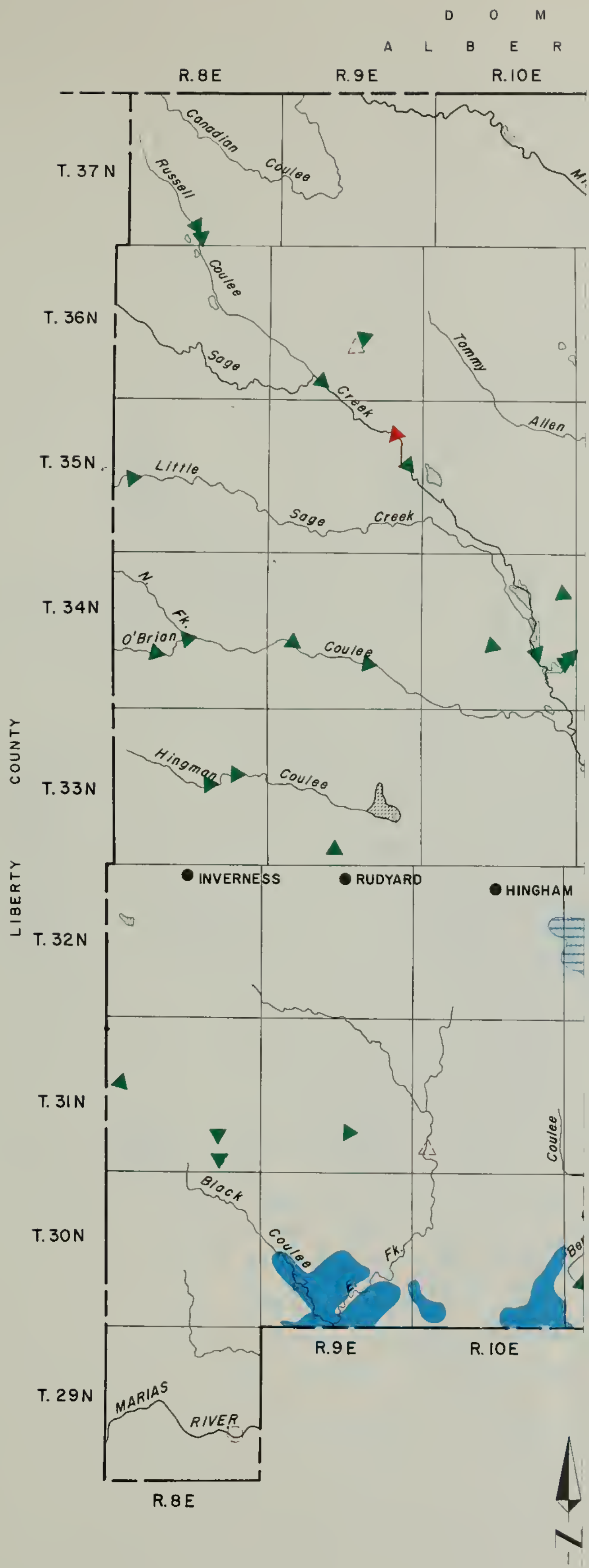
PHILLIPS COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Irrigated under Functional Plan
DOMINION OF CANADA
SASKATCHEWAN
R 27E
R 28E
R 29E
R 30E
R 31E
R 32E
R 33E
R 34E
R 35E
R 26E
R 25E
R 24E
R 23E
R 22E
T 37N
T 36N
T 35N
T 34N
T 33N
T 32N
T 31N
T 30N
T 29N
T 28N
T 27N
T 26N
T 25N
T 24N
T 23N
T 22N
T 21N
T 20N
LORING
WHITEWATER
SACO
DODSON
WAGNER
MALTA
BELKNAP
REGINA
ZORTMAN
LANDUSKY
INDIAN
RESERVATION
LEWIS & CLARK
NATIONAL
FOREST
CHARLES M. RUSSELL NATIONAL WILDLIFE RANGE
FORT PECK
RESERVOIR
MISSOURI
RIVER
Nelson Reservoir
Frenchman Reservoir
Whitewater Reservoir



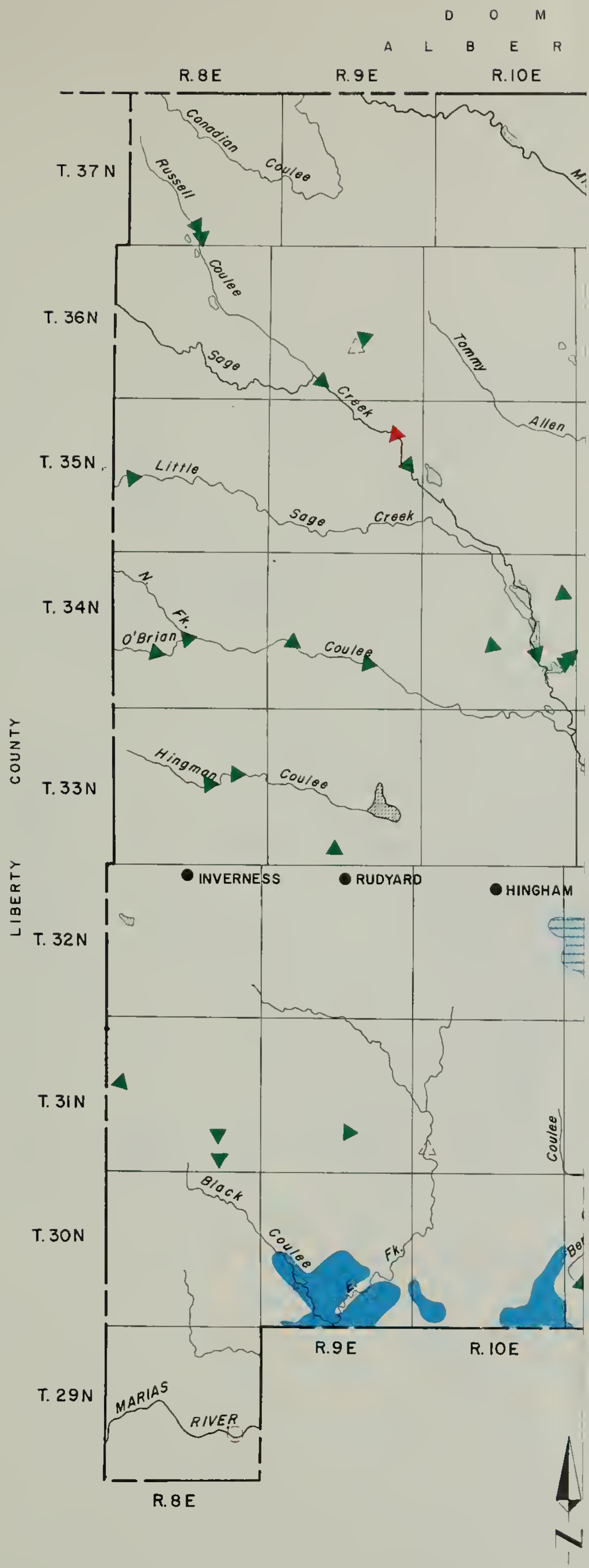
DOMINION OF CANADA
SASKATCHEWAN
R. 17E
R. 18E
R. 19E
R. 20E
R. 21E
R. 22E
R. 23E
R. 24E
R. 25E
R. 26E
T. 37N
T. 36N
T. 35N
T. 26N
T. 25N
T. 24N
T. 23N
Alkali Lake
Irvins Creek
Bennett Creek
Coulee
Island
Murry Coulee
Buckley Coulee
HOGELAND
TURNER
Battle Creek
Battle
Corral Creek
Fk.
Hay Coulee
Lodge
Woody
Silver Bow Lake
Chouteau
Creek
Mile
NORTH CHINOOK RESERVOIR
Suction
Fort
HAYS
Little Creek
W. Fk Black
E. Fk Black
Bullwackers
Das Coulee
Right Coulee
Left Coulee
Cow
Squaw
Lion Creek
Bills Coulee
Block
Missouri
River
CHOUTEAU COUNTY
FERGUS COUNTY
PHILLIPS COUNTY
BLAINE COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Irrigated under Functional Plan
N


D O M I N I O N O F C A N A D A
S A S K A T C H E W A N
R. 17E
R. 18E
R. 19E
R. 20E
R. 21E
R. 22E
R. 23E
R. 24E
R. 25E
R. 26E
T. 37N
T. 36N
T. 35N
T. 26N
T. 25N
T. 24N
T. 23N
Alkali Lake
Island
Coulee
Murry Coulee
HOGELAND
Buckley
TURNER
Woody
Silver Bow Lake
Irvins
Creek
Bennett
Corral
Battle
Hay
Coulee
Lodge
Chouteau
NORTH CHINOOK RESERVOIR
Mile
Suction
FORT
HAYS
Little
Bullwackers
Das
Right
Left
Cow
Squaw
Lion
Bills
Black
Fk
Missouri
River
PHILLIPS COUNTY
FERGUS COUNTY
CHOUTEAU COUNTY
N
BLAINE COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Irrigated under Functional Plan

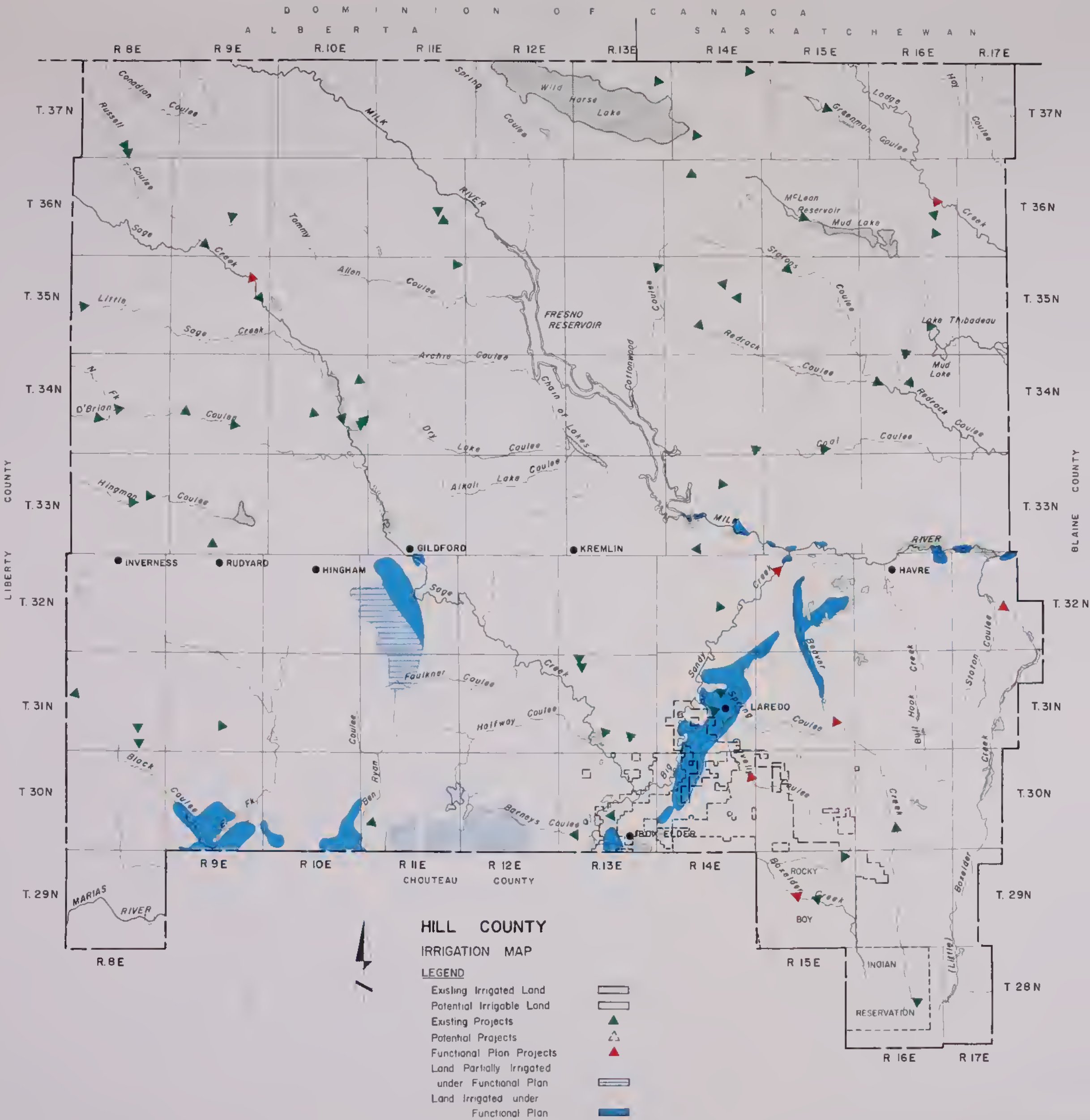

DOMINION OF CANADA
SASKATCHEWAN
HILL COUNTY
PHILLIPS COUNTY
CHOUTEAU COUNTY
FERGUS COUNTY
CHINOOK
ZURICH
HARLEM
SAVOY
HOGELAND
TURNER
LLOYD
CLEVELAND
LODGE POLE
HAYS
NORTH CHINOOK RESERVOIR
MILK RIVER
FORT BELKNAP INDIAN RESERVATION
BOUNDARY
BLAINE COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Irrigated under Functional Plan

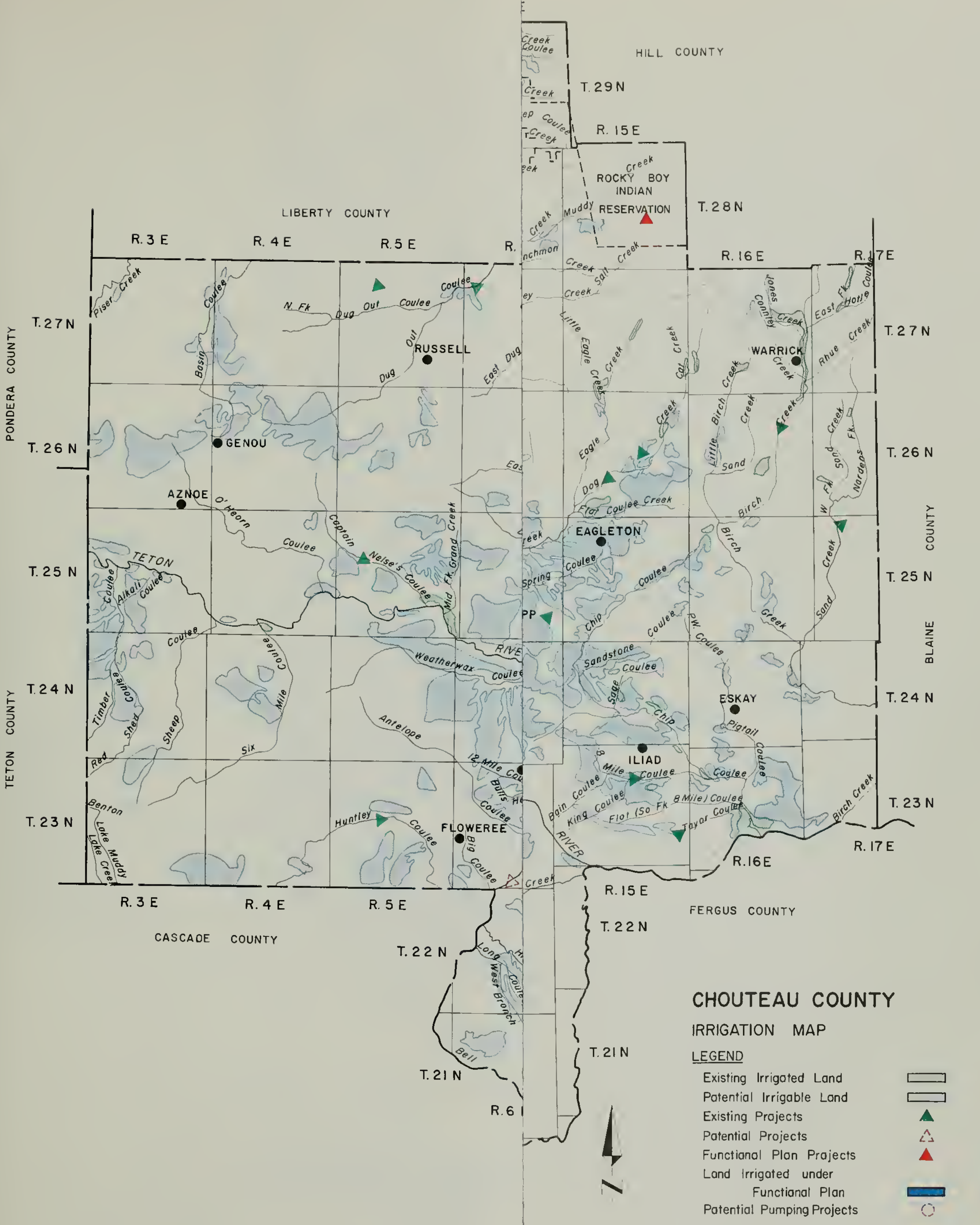


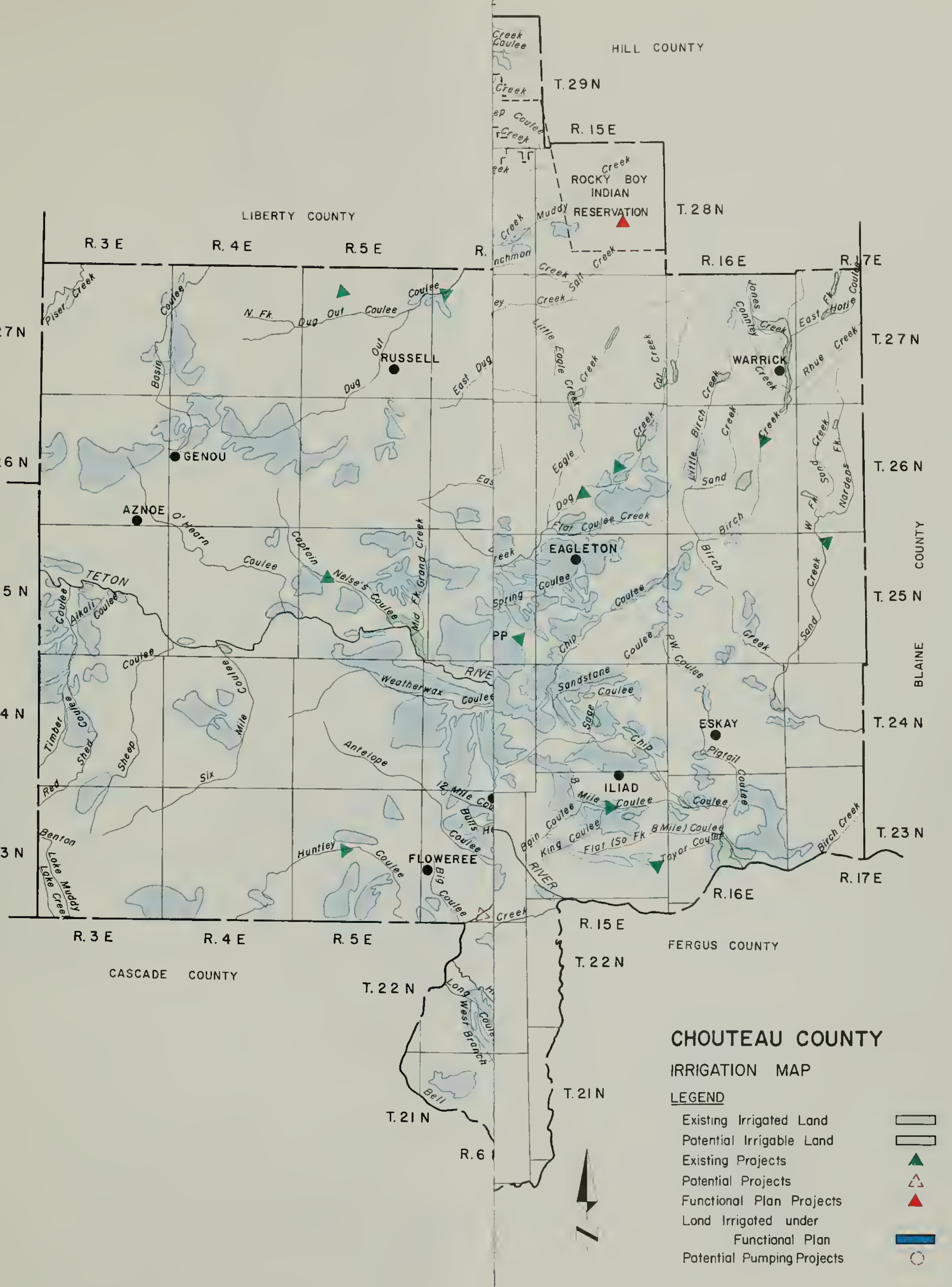
D O M
A L B E R
R. 8 E
R. 9 E
R. 10 E
T. 37 N
T. 36 N
T. 35 N
T. 34 N
T. 33 N
T. 32 N
T. 31 N
T. 30 N
T. 29 N
Canadian
Coulee
Russell
Coulee
Sage
Creek
Tommy
Allen
Little
Sage
Creek
N.
Fk.
O'Brian
Coulee
Hingman
Coulee
INVERNESS
RUDYARD
HINGHAM
Coulee
Black
Coulee
E.
Fk.
MARIAS
RIVER
LIBERTY COUNTY
R. 9 E
R. 10 E
R. 8 E

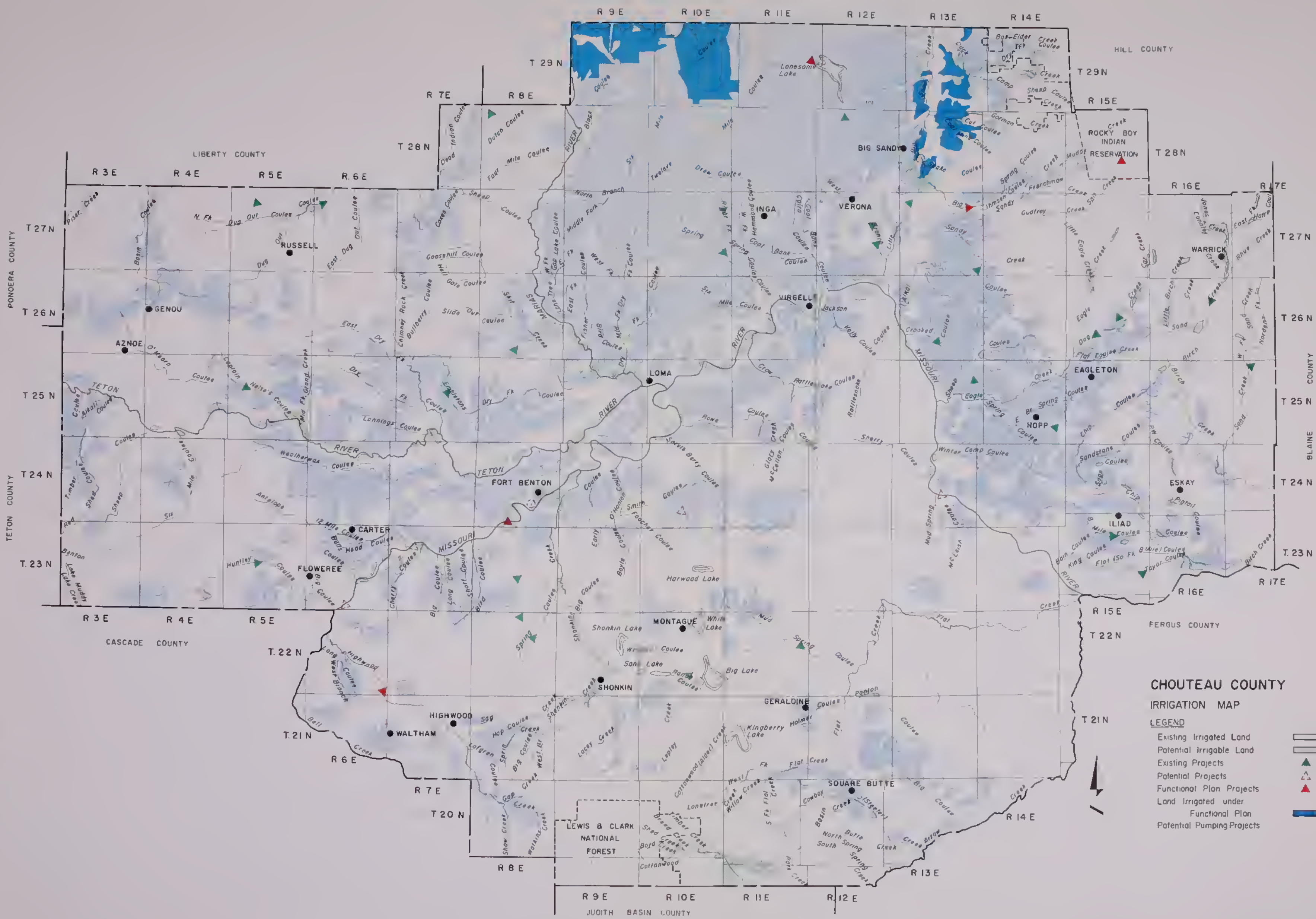


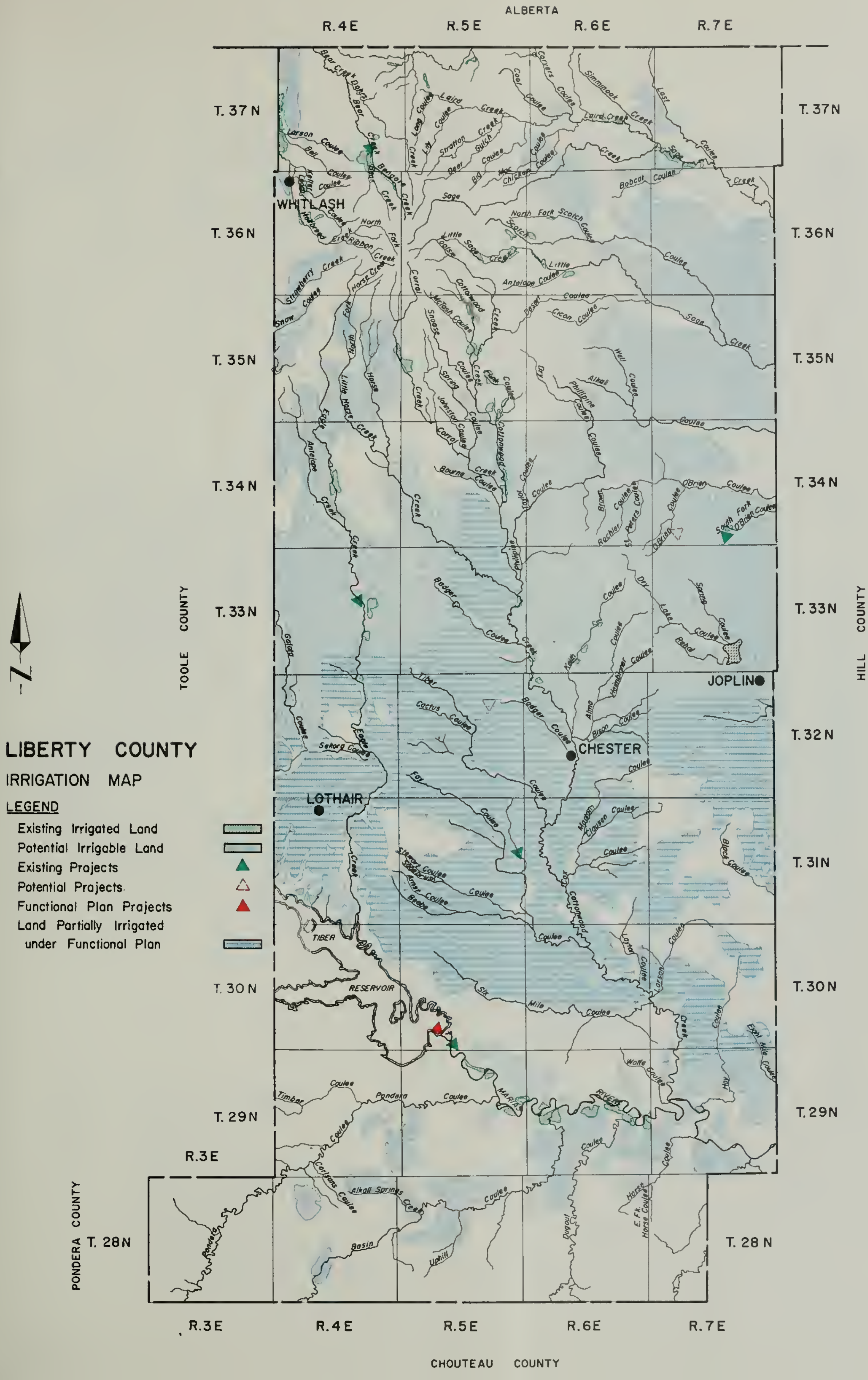
D O M
A L B E R
R. 8 E
R. 9 E
R. 10 E
T. 37 N
T. 36 N
T. 35 N
T. 34 N
T. 33 N
T. 32 N
T. 31 N
T. 30 N
T. 29 N
LIBERTY COUNTY
Canadian Coulee
Russell Coulee
Sage Creek
Tommy Allen
Little Sage Creek
N. Fk. O'Brian Coulee
Hingman Coulee
INVERNESS
RUDYARD
HINGHAM
Coulee
Black Coulee
E. Fk.
MARIAS RIVER
R. 9 E
R. 10 E
R. 8 E

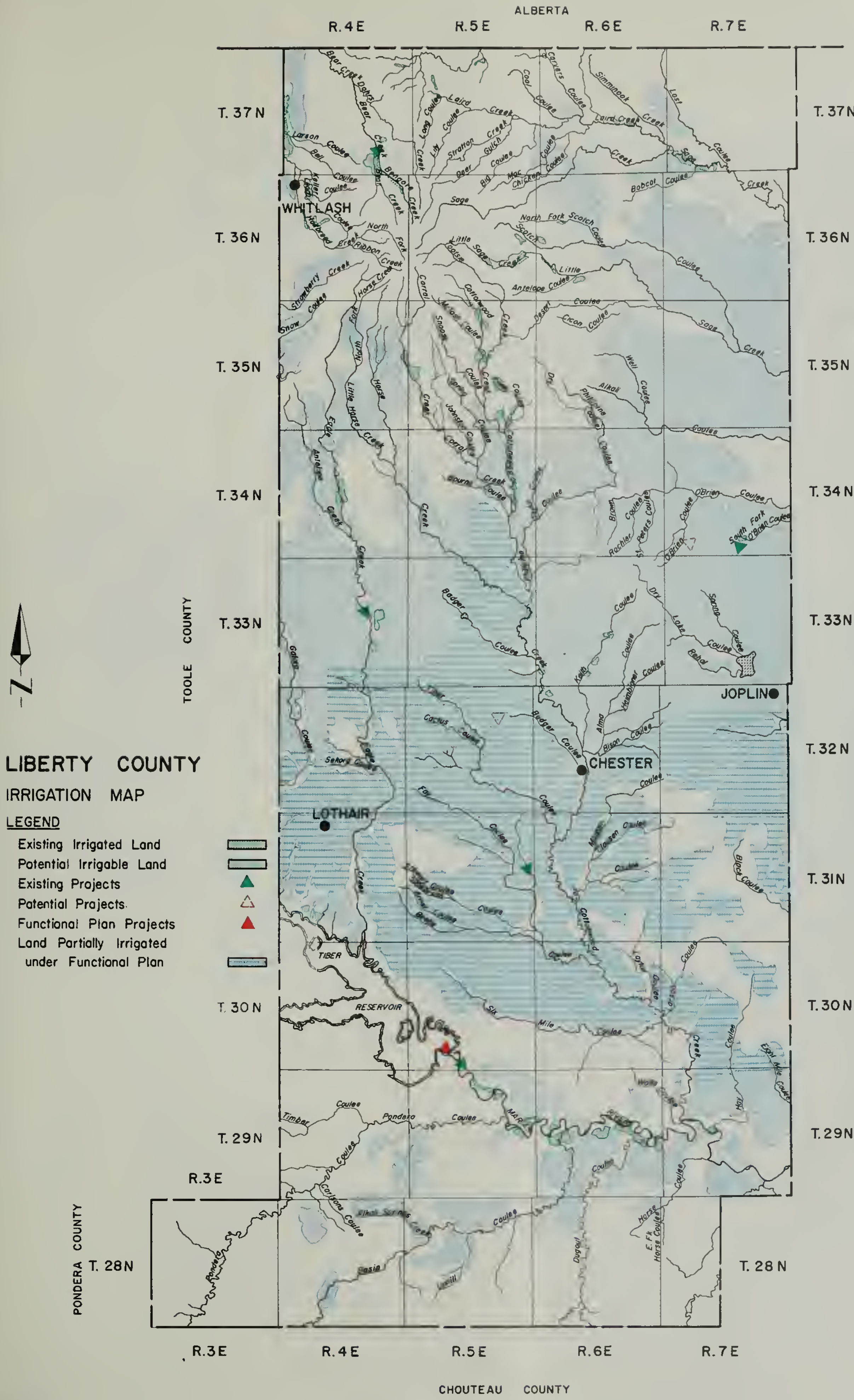

DOMINION OF CANADA
ALBERTA
SASKATCHEWAN
R 8E
R 9E
R.10E
R 11E
R 12E
R.13E
R 14E
R 15E
R 16E
R.17E
T. 37N
T 36N
T. 35N
T. 34N
T. 33N
T. 32N
T. 31N
T. 30N
T. 29N
T 28N
LIBERTY COUNTY
BLAINE COUNTY
CHOUTEAU COUNTY
Wild Horse Lake
MILK RIVER
FRESNO RESERVOIR
McLean Reservoir
Mud Lake
Lake Thibadeau
GILDFORD
KREMLIN
INVERNESS
RUDYARD
HINGHAM
HAVRE
LAREDO
BOX ELDER
ROCKY BOY INDIAN RESERVATION
MARIAS RIVER
HILL COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Partially Irrigated under Functional Plan
Land Irrigated under Functional Plan


CHOUTEAU COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Irrigated under Functional Plan
Potential Pumping Projects
HILL COUNTY
LIBERTY COUNTY
PONDERA COUNTY
TETON COUNTY
CASCADE COUNTY
FERGUS COUNTY
BLAINE COUNTY
ROCKY BOY INDIAN RESERVATION
RUSSELL
GENOU
AZNOE
EAGLETON
WARRICK
ESKAY
ILIAD
FLOWEREE
TETON
RIVER
T. 29 N
T. 28 N
T. 27 N
T. 26 N
T. 25 N
T. 24 N
T. 23 N
T. 22 N
T. 21 N
R. 3 E
R. 4 E
R. 5 E
R. 6
R. 15 E
R. 16 E
R. 17 E

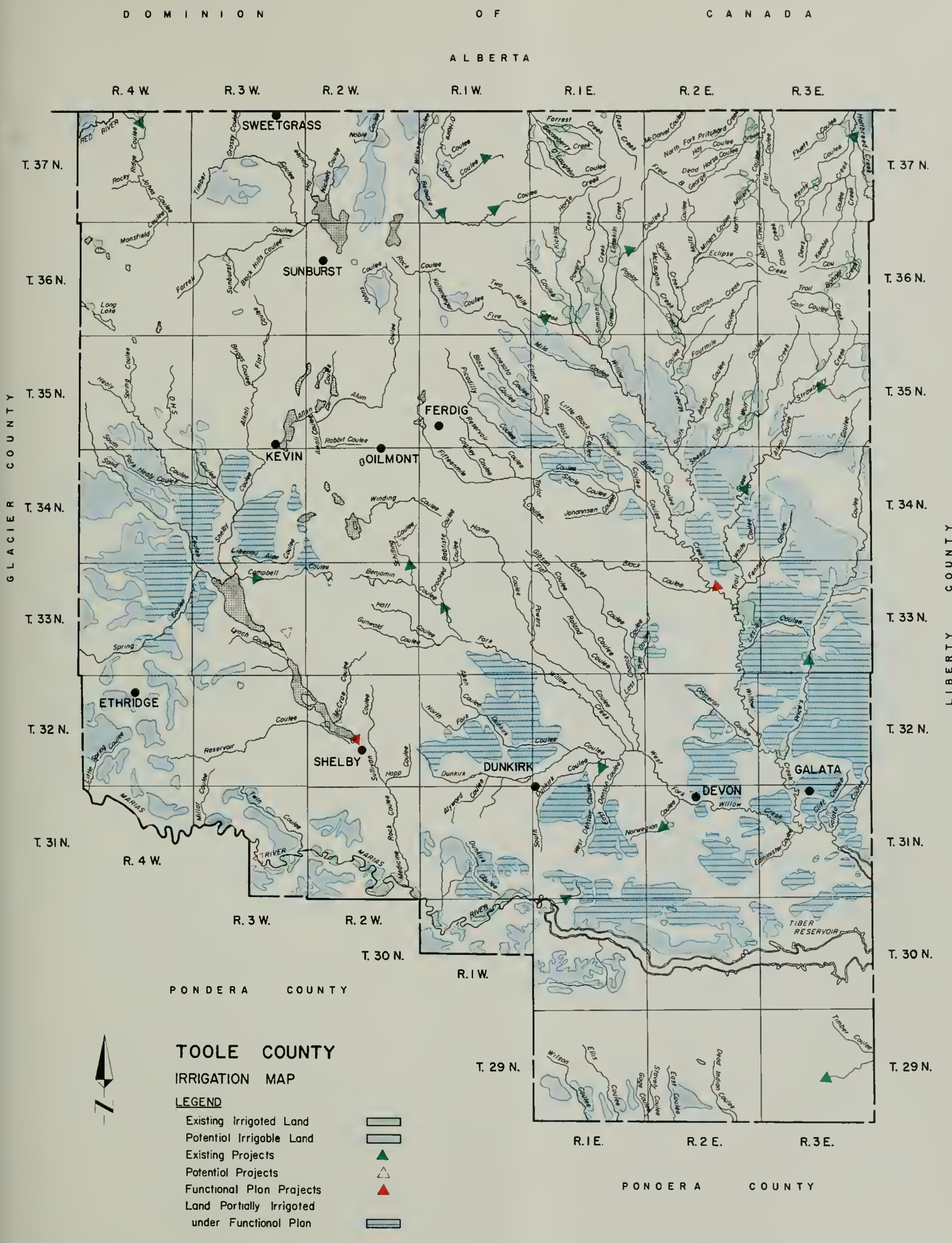

CHOUTEAU COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Irrigated under Functional Plan
Potential Pumping Projects
HILL COUNTY
LIBERTY COUNTY
PONDERA COUNTY
TETON COUNTY
CASCADE COUNTY
FERGUS COUNTY
BLAINE COUNTY
ROCKY BOY INDIAN RESERVATION
T. 29 N
T. 28 N
T. 27 N
T. 26 N
T. 25 N
T. 24 N
T. 23 N
T. 22 N
T. 21 N
R. 3 E
R. 4 E
R. 5 E
R. 6 E
R. 15 E
R. 16 E
R. 17 E
RUSSELL
GENOU
AZNOE
EAGLETON
WARRICK
ESKAY
ILIAD
FLOWEREE
TETON
RIVER
Weatherwax Coulee
Antelope
Sandstone Coulee
Flat Coulee Creek
Dug Out Coulee
Birch Creek
Pigtail Coulee
Huntley Coulee
Big Coulee
12 Mile Coulee
Sixmile Coulee
Nelse's Coulee
Captain
Mid Fk Grand Creek
Spring Coulee
Chip Coulee
Eagle Creek
Little Eagle Creek
Dog Creek
Cat Creek
Sand Creek
Little Birch Creek
Jones Coulee
East Fk Horse Coulee
Rhue Creek
Nardens
Benton Lake
Muddy Creek
Timber Coulee
Shed
Sheep
Red
Alkali Coulee
O'Hearn Coulee
Basin Coulee
Piser Creek
N. Fk.
East Dug
King Coulee
Bain Coulee
Flat (So Fk 8 Mile) Coulee
Tayor Coulee
Long Coulee
West Branch
Bell
Salt Creek
Muddy
Sage


CHOUTEAU COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Irrigated under Functional Plan
Potential Pumping Projects
HILL COUNTY
LIBERTY COUNTY
PONDERA COUNTY
TETON COUNTY
CASCADE COUNTY
JUDITH BASIN COUNTY
FERGUS COUNTY
BLAINE COUNTY
ROCKY BOY INDIAN RESERVATION
LEWIS & CLARK NATIONAL FOREST
R 3 E
R 4 E
R 5 E
R 6 E
R 7 E
R 8 E
R 9 E
R 10 E
R 11 E
R 12 E
R 13 E
R 14 E
R 15 E
R 16 E
R 17 E
T 29 N
T 28 N
T 27 N
T 26 N
T 25 N
T 24 N
T 23 N
T 22 N
T 21 N
T 20 N
BIG SANDY
VERONA
INGA
RUSSELL
GENOU
AZNOE
VIRGELLE
LOMA
WARRICK
EAGLETON
NOPP
ESKAY
ILIAD
FORT BENTON
CARTER
FLOWEREE
MONTAGUE
SHONKIN
GERALDINE
HIGHWOOD
WALTHAM
SQUARE BUTTE
MISSOURI RIVER
TETON RIVER
MARIAS RIVER
Lonesome Lake
Harwood Lake
Shonkin Lake
White Lake
Big Lake
Sand Lake
Kingberry Lake


LIBERTY COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Partially Irrigated under Functional Plan
ALBERTA
R.3E
R.4E
R.5E
R.6E
R.7E
T. 37 N
T. 36 N
T. 35 N
T. 34 N
T. 33 N
T. 32 N
T. 31 N
T. 30 N
T. 29 N
T. 28 N
TOOLE COUNTY
HILL COUNTY
PONDERA COUNTY
CHOUTEAU COUNTY
WHITLASH
JOPLIN
CHESTER
LOTHAIR
TIBER
RESERVOIR
MARIAS RIVER
N



ALBERTA
R.4E
R.5E
R.6E
R.7E
T. 37 N
T. 36 N
T. 35 N
T. 34 N
T. 33 N
T. 32 N
T. 31 N
T. 30 N
T. 29 N
T. 28 N
R.3E
WHITLASH
JOPLIN
CHESTER
LOTHAIR
TIBER
RESERVOIR
TOOLE COUNTY
HILL COUNTY
PONDERA COUNTY
CHOUTEAU COUNTY
N
LIBERTY COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Partially Irrigated
under Functional Plan
R.3E
R.4E
R.5E
R.6E
R.7E



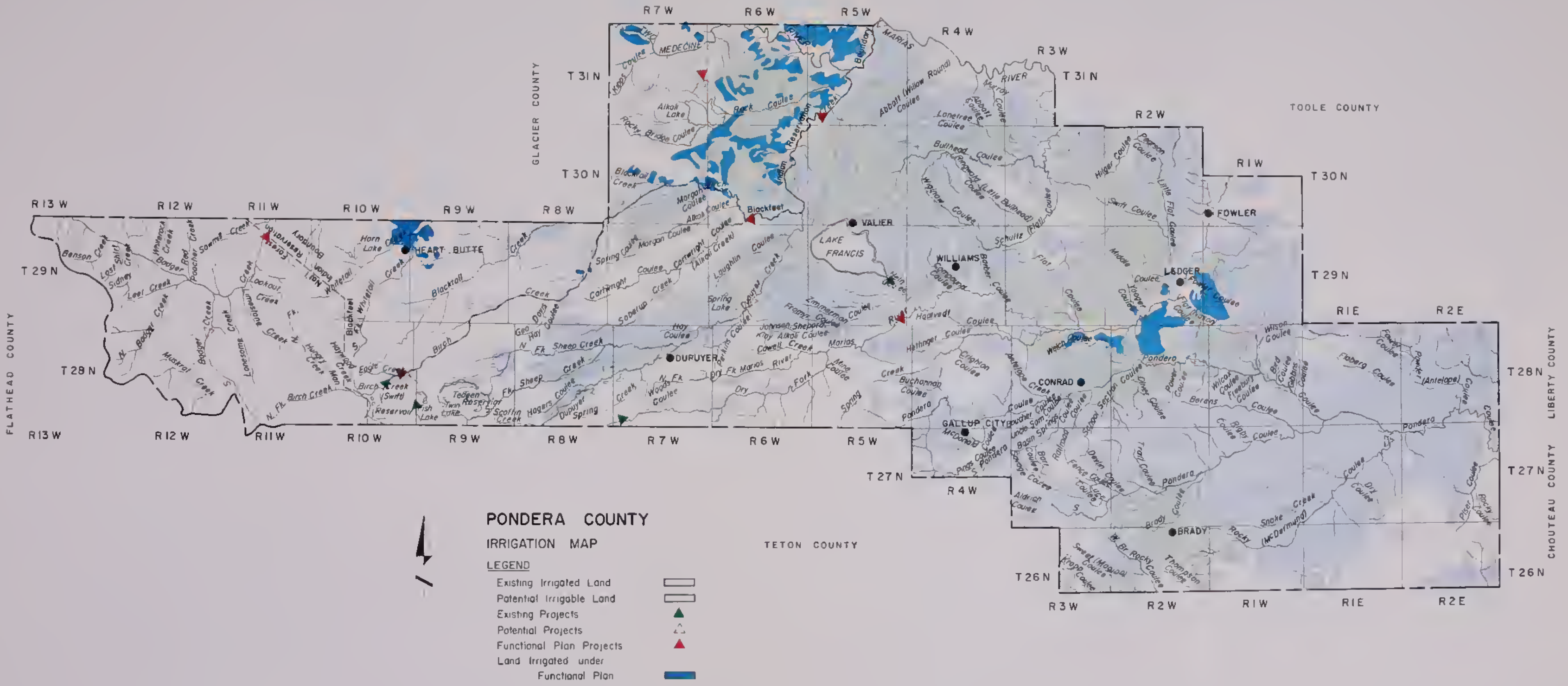
TOOLE COUNTY

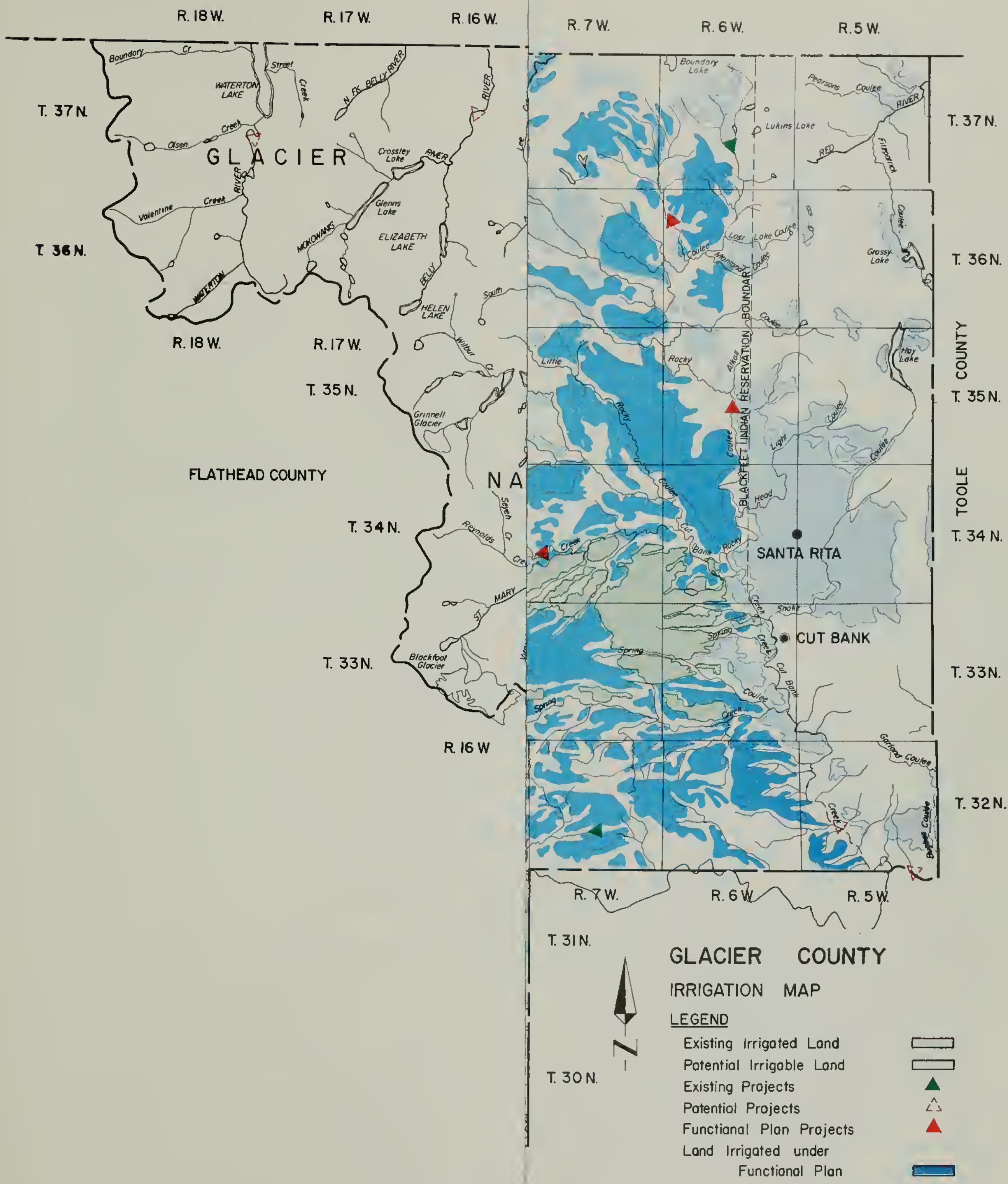
IRRIGATION MAP

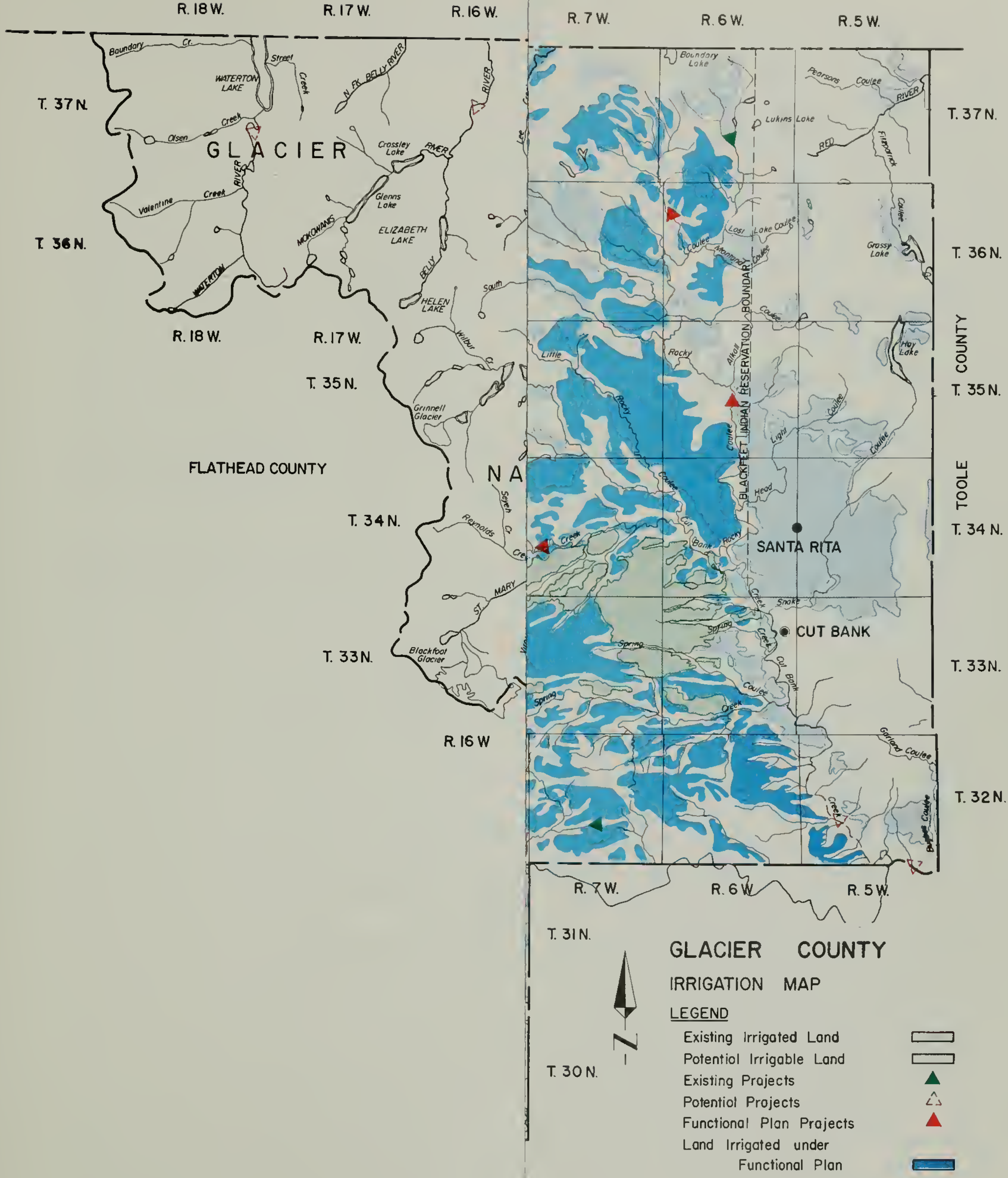
LEGEND

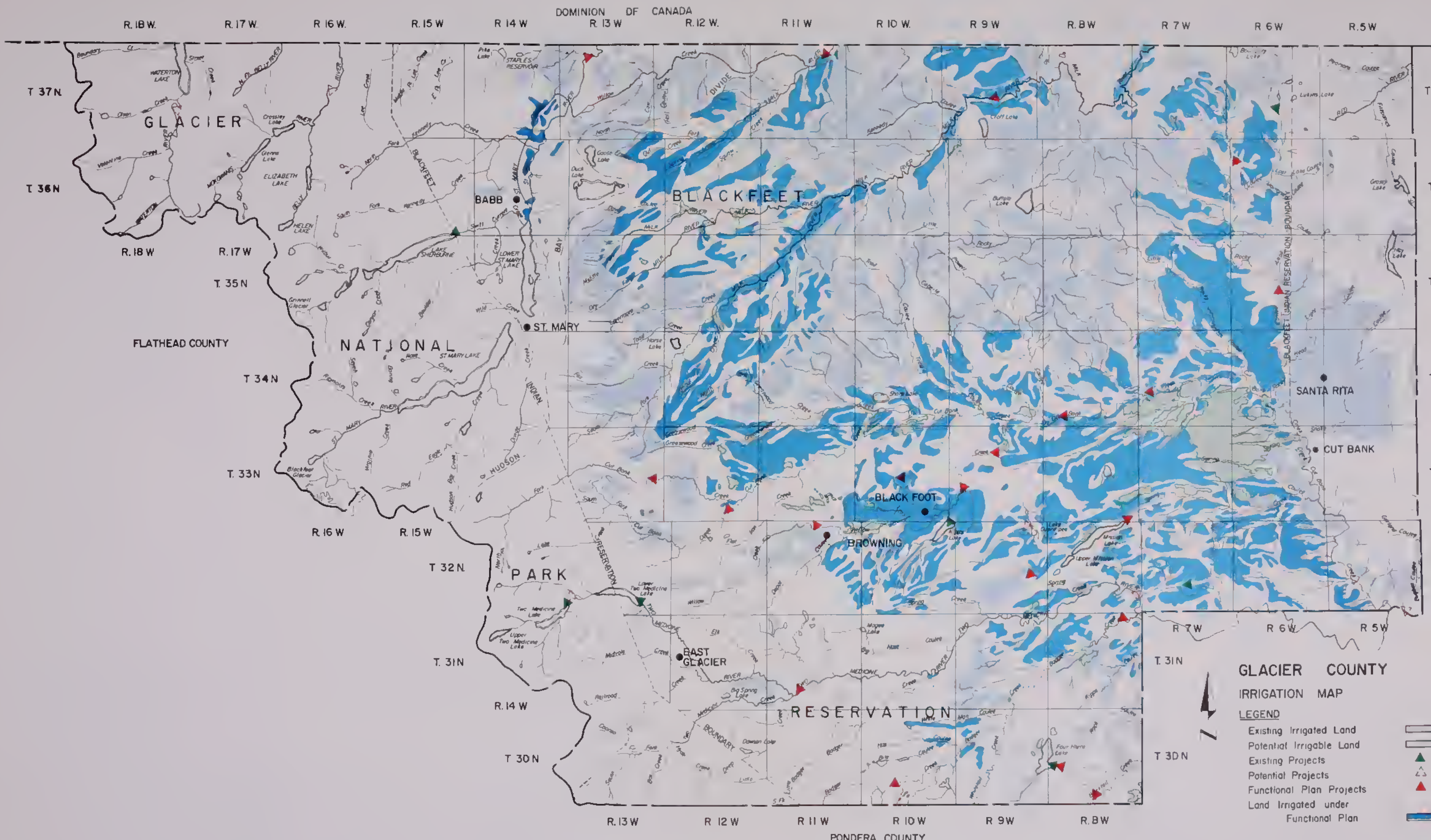
- Existing Irrigated Land
- Potential Irrigable Land
- Existing Projects
- Potential Projects
- Functional Plan Projects
- Land Partially Irrigated under Functional Plan


TOOLE COUNTY
FLATHEAD COUNTY
LIBERTY COUNTY
CHOUTEAU COUNTY
R13 W
R12 W
R11 W
R1 W
R1 E
R2 E
T30 N
T29 N
T28 N
T27 N
T26 N
FOWLER
BRADY
Benson Creek
Lost Shirt
Sidney
Creek
Whiterock Creek
Red Creek
Badger
Poocher Creek
Sowmill Creek
Leel Creek
Lookout Creek
Limestone Creek
Lonesome Creek
Badger Creek
Muskrat Creek
N. Badger Creek
Birch
N. Fk.
Fowler Coulee
Flat (Nason) Coulee
Wilson Coulee
Wilcox Coulee
Freebury Coulee
Bird Coulee
Gibbins Coulee
Berens Coulee
Rigby Coulee
Flaberg Coulee
Powder (Antelope) Coulee
Pondera
Dry Coulee
Snake Creek
Rocky (McDermund)
Piser Coulee
Rocky Coulee


PONDERA COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Irrigated under Functional Plan
GLACIER COUNTY
TOOLE COUNTY
TETON COUNTY
FLATHEAD COUNTY
LIBERTY COUNTY
CHOUTEAU COUNTY
VALIER
LAKE FRANCIS
WILLIAMS
FOWLER
LEDGER
CONRAD
DUPUYER
HEART BUTTE
GALLUP CITY
BRADY
MARIAS RIVER
T 31 N
T 30 N
T 29 N
T 28 N
T 27 N
T 26 N
R 13 W
R 12 W
R 11 W
R 10 W
R 9 W
R 8 W
R 7 W
R 6 W
R 5 W
R 4 W
R 3 W
R 2 W
R 1 W
R 1 E
R 2 E


GLACIER COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Irrigated under Functional Plan
GLACIER
NA
FLATHEAD COUNTY
TOOLE COUNTY
SANTA RITA
CUT BANK
BLACKFEET INDIAN RESERVATION BOUNDARY
R. 18 W.
R. 17 W.
R. 16 W.
R. 7 W.
R. 6 W.
R. 5 W.
T. 37 N.
T. 36 N.
T. 35 N.
T. 34 N.
T. 33 N.
T. 32 N.
T. 31 N.
T. 30 N.
WATERTON LAKE
Crossley Lake
Glenns Lake
ELIZABETH LAKE
HELEN LAKE
Grinnell Glacier
Blackfoot Glacier
Boundary Lake
Lukins Lake
Grassy Lake
Hay Lake


GLACIER COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Irrigated under Functional Plan
R. 18 W.
R. 17 W.
R. 16 W.
R. 7 W.
R. 6 W.
R. 5 W.
T. 37 N.
T. 36 N.
T. 35 N.
T. 34 N.
T. 33 N.
T. 32 N.
T. 31 N.
T. 30 N.
GLACIER
NA
FLATHEAD COUNTY
TOOLE COUNTY
BLACKFEET INDIAN RESERVATION BOUNDARY
SANTA RITA
CUT BANK
WATERTON LAKE
Boundary Cr.
Street Creek
N. FK. BELLY RIVER
Olsen Creek
Valentine Creek
Crossley Lake
Glenns Lake
ELIZABETH LAKE
HELEN LAKE
MOKOWANS
WATERTON
BELLY
Grinnell Glacier
Blackfoot Glacier
Reynolds Creek
ST. MARY
Boundary Lake
Pearsons Coulee
Lukins Lake
RED RIVER
Lost Lake Coulee
Grassy Lake
Hay Lake
Rocky Coulee
Cut Bank Creek
Snake
Spring Creek
Garland Coulee


GLACIER COUNTY
IRRIGATION MAP
LEGEND
Existing Irrigated Land
Potential Irrigable Land
Existing Projects
Potential Projects
Functional Plan Projects
Land Irrigated under Functional Plan
DOMINION OF CANADA
FLATHEAD COUNTY
TOOLE COUNTY
PONDERA COUNTY
GLACIER NATIONAL PARK
BLACKFEET INDIAN RESERVATION
BLACKFEET INDIAN RESERVATION BOUNDARY
BABB
ST. MARY
BLACK FOOT
BROWNING
EAST GLACIER
SANTA RITA
CUT BANK
R. 18 W.
R. 17 W.
R. 16 W.
R. 15 W
R. 14 W
R. 13 W.
R. 12 W.
R. 11 W
R. 10 W.
R. 9 W
R. 8 W
R. 7 W
R. 6 W
R. 5 W
T. 37 N.
T. 36 N
T. 35 N
T. 34 N
T. 33 N.
T. 32 N
T. 31 N
T. 30 N
STAPLES RESERVOIR
WATERTON LAKE
ELIZABETH LAKE
HELEN LAKE
LAKE SHERBURNE
LOWER ST. MARY LAKE
ST. MARY LAKE
Lower Two Medicine Lake
Two Medicine Lake
Upper Two Medicine Lake
Grinnell Glacier
Blackfoot Glacier
MILK RIVER
ST. MARY RIVER
TWO MEDICINE RIVER
DIVIDE

In the optimization model there were 14 potential projects on tributaries to the Milk River, exclusive of projects on the Indian reservations. Of these 13 were selected by the optimization model as being worthy of further study. The fourteenth, Beaver Creek project in Phillips County, was located immediately downstream of a second potential project, Reservoir No. 1, that was selected and of such a size that the Beaver Creek project was not needed to fully develop the Beaver Creek flows.

It should be emphasized that while the model does test for flow balance between every possible combination of projects with the size of each project being a variable quantity in the solution and while it gives a good indication of which projects will be economically feasible, it should not be expected to provide the optimum size for each of the projects. It is true that the size selected by the computer is the size which gave the optimum solution in terms of net benefits (or costs, depending on the objective function selected), but it should be remembered that a two-season representation of flows was selected for this preliminary survey. While the two-season representation is adequate for purposes of this study and is consistent with the level of detail in the available data, sizing of individual projects would have to be based on at least a twelve-season - or monthly - model. This level of detail would be appropriate during the feasibility studies when detailed soils, topographic, and geologic information is available for each site.

The 13 projects on Milk River tributaries which were selected by the model, listed from upstream tributaries downstream, are:

1. No. 538, Big Sandy Creek project in Chouteau County.

2. No. 541, Lonesome Lake project on 12 Mile Coulee in Couteau County.

3. No. 545, Sage Creek project in Hill County.

4. No. 546, Big Sandy Creek project in Hill County.

5. No. 547, Beaver Creek project in Hill County.

6. No. 548, Box Elder project on Little Box Elder Creek in Hill County.

7. No. 550, Lodge Creek project in Hill County.

8. No. 551, Battle Creek project on Battle Creek in Blaine County.

9. No. 549, Savoy Creek project in Blaine County.

10. No. 554, Reservoir No. 1 on Beaver Creek in Phillips County.

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The 13 projects on Milk River tributaries which were selected by the model, listed from upstream tributaries downstream, are:

1. No. 538, Big Sandy Creek project in Chouteau County.
2. No. 541, Lonesome Lake project on 12 Mile Coulee in Couteau County.
3. No. 545, Sage Creek project in Hill County.
4. No. 546, Big Sandy Creek project in Hill County.
5. No. 547, Beaver Creek project in Hill County.
6. No. 548, Box Elder project on Little Box Elder Creek in Hill County.
7. No. 550, Lodge Creek project in Hill County.
8. No. 551, Battle Creek project on Battle Creek in Blaine County.
9. No. 549, Savoy Creek project in Blaine County.
10. No. 554, Reservoir No. 1 on Beaver Creek in Phillips County.

11. No. 552, Whitewater Creek project in Phillips County.

12. No. 555, Rock Creek project in Valley County.

13. No. 556, Willow Creek project in Valley County.

These projects could supply water to as much as 273, 100 acres in and along the Milk River Valley based on the potentially irrigable land as shown in this report. Most of these projects were originally proposed during the early 1930's and many have not been studied since. Exceptions are Beaver Creek project in Hill County, Lodge and Battle Creek projects in Blaine County, and Willow Creek project in Valley County.

Beaver Creek Dam and Reservoir in Hill County. The objectives of this watershed project proposed by the Soil Conservation Service are: to increase the efficiency of irrigation water management and land use practices; to provide flood protection on 1, 771 acres along Beaver Creek; to supply supplemental irrigation water on 1, 800 acres; to provide water-based recreation and associated facilities; to stabilize stream flow for fishery management; and to alleviate seepage and water loss associated with Sands Reservoir. A total of 4, 042 acres would be benefited by the structural measures. This includes 646 acres in Beaver Creek Park and 175 acres receiving both irrigation and flood prevention benefits.

Structural measures to be installed include a multipurpose reservoir, water measuring devices, an irrigation diversion structure and canal headworks, and recreational facilities. The reservoir would have a total storage capacity of 7, 230 acre-feet, an area of 204 acres, a length of 6, 800 feet, an average width of 1, 000 feet, and a maximum depth of 92. 5 feet. Of this capacity the recreational and fish and wildlife pool would contain 2, 998 acre-feet, including 870 acre-feet of sediment storage. Supplemental irrigation storage would be 937 acre-feet; dual purpose supplemental irrigation and flood prevention storage would be 2, 185 acre-feet; and 1, 110 acre-feet would provide additional flood protection. The maximum height of the structure would be 97. 5 feet with a crest length of 2, 680 feet. The embankment would contain about 930, 000 cubic yards.

The estimated total project installation cost is $1, 160, 740 (1967 prices), of which $951, 975 would be for structural measures. These costs would be allocated among the project purposes and shared between Public Law 566 funds and other funds according to the provisions of the Act.

Operation and maintenance of structural measures will be the responsibility of the local sponsors and is estimated at $4, 710 per year. Operation, maintenance, and replacement of expandable recreational facilities will be the responsibility of Hill County. Estimated average annual cost is $12, 546, of which $8, 073 is the adjusted normalized cost of restocking trout.

Average annual monetary benefits accruing to structural measures are estimated at $154, 515, including $18, 975 from flood prevention, $57, 615 from irrigation, $57, 930 from recreation, $1, 725 from fish and wildlife, and $18, 270 from secondary benefits. The average annual costs of these structural measures, including amortization of investment, operation, maintenance, and replacement were estimated at $49, 509, based on 1967 prices amortized over 100 years at 3 1/4 percent interest.

North Chinook Project in Blaine County. The existing North Chinook Project is north of Chinook and includes Lodge Creek and Battle Creek drainage. The existing project was constructed in 1910 and consists of a 7, 000 A. F. offstream reservoir with a 25 c. f. s. supply canal from Lodge Creek. The project is presently supplying water to approximately 2, 000 acres of benchland between Lodge Creek and Battle Creek, and land in the valley bottom along Battle Creek.

In 1940 the State Water Conservation Board authorized a preliminary survey for a storage reservoir on Lodge Creek. The Lodge Creek site is located in Section 14, Township 36 North, Range 16 East. The proposal consists of a 52-foot high dam having a crest length of 1, 550 feet, and a storage capacity of 17, 500 A. F. at normal water surface. The prime purpose for the project proposed is for irrigation and flood control. In 1966 it was estimated that the structure would cost roughly $675, 000. Adjusting this to 1970 prices the cost would be approximately $800, 000.

In 1965, the State Water Conservation Board investigated the possibility of increasing the capacity of the present supply canal from Lodge Creek into the existing North Chinook Reservoir. This proposal is for the enlargement of this 5-mile long canal from 25 c. f. s. to 200 c. f. s. At today's prices, this would probably cost approximately $50, 000.

As a part of the 1965 studies, the State Water Conservation Board was requested to investigate possible means of diversion or storage of excess flood flows on Battle Creek. The Battle Creek site investigated is located in Section 9, Township 36 North, Range 18 East. The proposed reservoir would have a normal storage capacity of 12, 200 A. F. and a maximum storage capacity, with spillway gates, of 19, 000 A. F. Incorporated in this structure would be an outlet that could divert water from the proposed reservoir into a supply canal, having a capacity of 100 c. f. s. that would supply the present North Chinook Reservoir. This would provide an alternate water supply to the existing North Chinook Reservoir and also irrigate the benchland between Lodge Creek and Battle Creek.

The total estimated cost for the 12, 200 A. F. reservoir would be approximately $808, 000 (1970 prices), excluding right-of-way. This reservoir with a water surface area of 1, 220 acres would require the purchase of approximately 1, 600 acres of land. To construct the supply canal to the existing North Chinook Project would require an additional expenditure of approximately $128, 000, plus right-of-way costs.

The irrigable land to be served by this Battle Creek Reservoir is located in the Battle Creek Valley and on the benchland between Lodge Creek and Battle Creek, and contains approximately 9,600 acres. Of this, approximately 2,000 acres is presently receiving a water supply from the North Chinook Project.

A third site on the East Fork of the Milk River was also investigated in 1965 while the State Water Conservation Board had a survey party in the area. This project would serve much of the same irrigable land as the Battle Creek site, and has not been considered in detail in this report.

Of the projects investigated, the State Water Conservation Board concluded that the Battle Creek proposal would provide the most benefits, as it could supply the existing reservoir with the construction of a diversion canal, provide water to the lands along Battle Creek, along with providing the flood control and recreation facilities.

Willow Creek Storage Project in Valley County. In 1966 the Montana State Water Conservation Board proposed to construct an earthfill dam to impound the waters of Willow Creek for irrigation, flood control and recreational purposes. A site was located and after preliminary surveys were completed, a petition was received signed by twenty-two potential water users requesting supplemental water for 8,000 acres under the project. The project water would be delivered through the Rock Creek Canal Company's existing canal, and no new canal for distribution is proposed.

The dam would have a crest length of 1,080 feet, and a maximum height above the stream bed of 90 feet. The storage capacity at spillway crest would be 25,000 acre-feet. An additional 5,000 acre-feet could be stored through the use of 4-foot spillway gates.

The reservoir has been designed for 25,000 acre-feet storage capacity, of which 22,150 acre-feet is proposed for irrigation under full development. The remainder will be for carry-over storage for low runoff years and for flood control.

The Rock Creek Canal Company will contract for waters from the project, to be used for irrigation. The Canal Company supplies water to a total of 9,600 acres. In addition to the land under the Rock Creek Canal Company, there is approximately 5,400 acres of new land that could be developed in the future, provided water is made available. To furnish water for full development of all 15,000 acres of land, an additional storage facility on Rock Creek or a supply canal from Rock Creek to the reservoir would be required.

The soils in this area range from Class II through Class VI, with a small amount of Class I. Only four ranches in the area which requested

water have been soil surveyed by the SCS and from these, it appears that only about 35 percent of the land would be Class I, II, or III irrigable. Class VI is applied to the Bowdoin clays in the area, which do produce reasonably well when used to raise native blue-joint hay; but because of the attendant mosquito and drainage problems associated with applying water to Bowdoin clays, irrigation of any additional Class VI land is not recommended unless it can definitely be shown that effective drainage will prevent future problems.

The total cost for construction of this project (escalated to 1970 prices) is estimated as $1,048,000. A revised economic analysis of the project based on the anticipated crops with the project was completed by the Montana Water Resources Board in the fall of 1968. This analysis estimated the benefit-cost ratio on direct benefits at 1.5:1. When total benefits were considered, the benefit-cost ratio became 3.6:1.

Other potential projects on Milk River Tributaries. Data on the other 10 projects selected by the computer is very limited. In fact, for these projects even preliminary project reports are not available.[3] It is fully realized that some of these proposed sites may prove to be unsuitable for geologic reasons or otherwise, but for purposes of this preliminary study it is sufficient to say that suitable sites should be sought on the tributaries selected and these should be investigated in more detail. There are also tributaries on which storage projects have not been proposed, such as Frenchman Creek, which because of their size should be investigated for storage possibilities.

In addition to the 13 non-Indian projects, there are 18 potential Indian projects on Milk River tributaries. The Indians rights to the use of water are protected by the "Winters Doctrine Rights" enunciated by the Supreme Court in 1908. The Winters Doctrine includes rights to provide for the ultimate needs of the Indians, and is intended to satisfy the future as well as present water needs of the Indians. Water requirements on Indian Reservations are not subject to optimization, as the Indians are entitled to sufficient water to meet all beneficial needs. For this reason, this study has considered that the Blackfeet, Rocky Boy, Fort Belknap, and Fort Peck (in Valley County) Indian Reservations would eventually use all of the water indicated as being necessary for full development in the No. 185 Potential Irrigation Development Report for each of the Reservations.

The No. 185 Reports consider ultimate development as taking place by the year 2020.[4] To indicate plans for development on the Reservations in the more immediate future, Figure X-2 depicts conditions through 1980 as indicated in the Plan of Completion Reports for the Reservations.

Development on non-Indian land is according to the functional plan, except that the Upper Marias Area is not included because of the probable time required to implement this project.

EXISTING SUPPLIES BASED ON 65% OF AVERAGE ANNUAL FLOWS

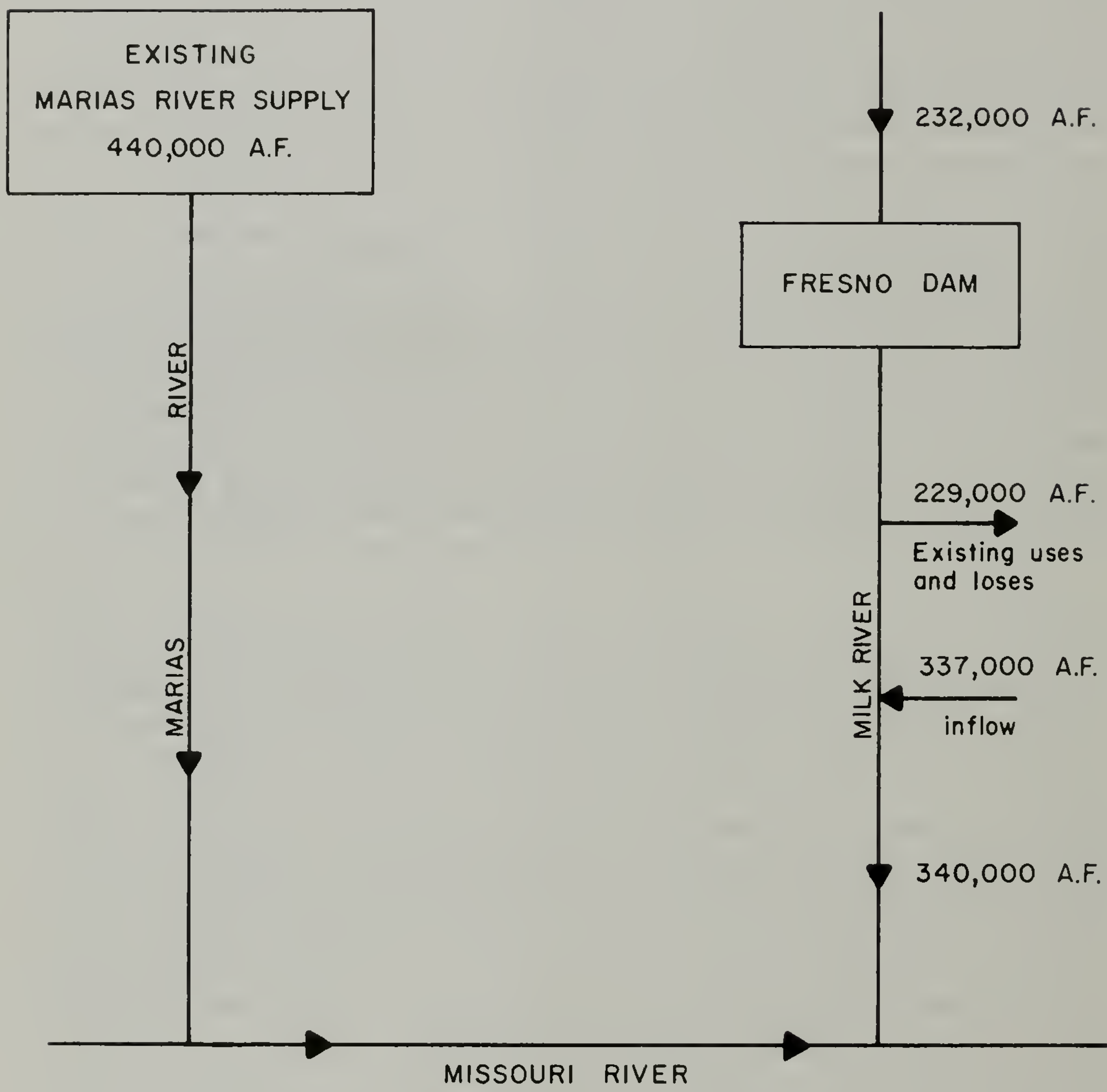
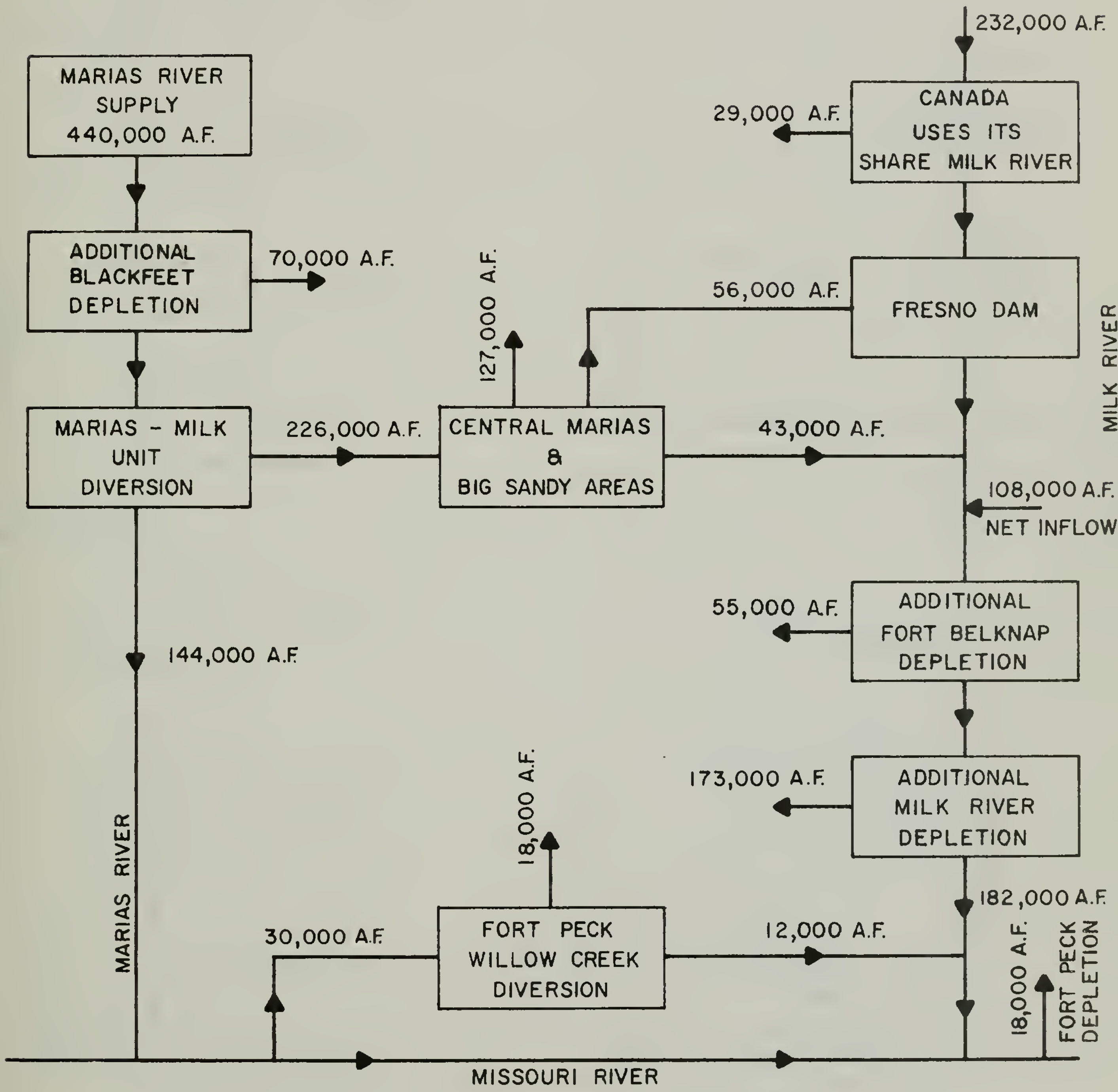


FIGURE X-1

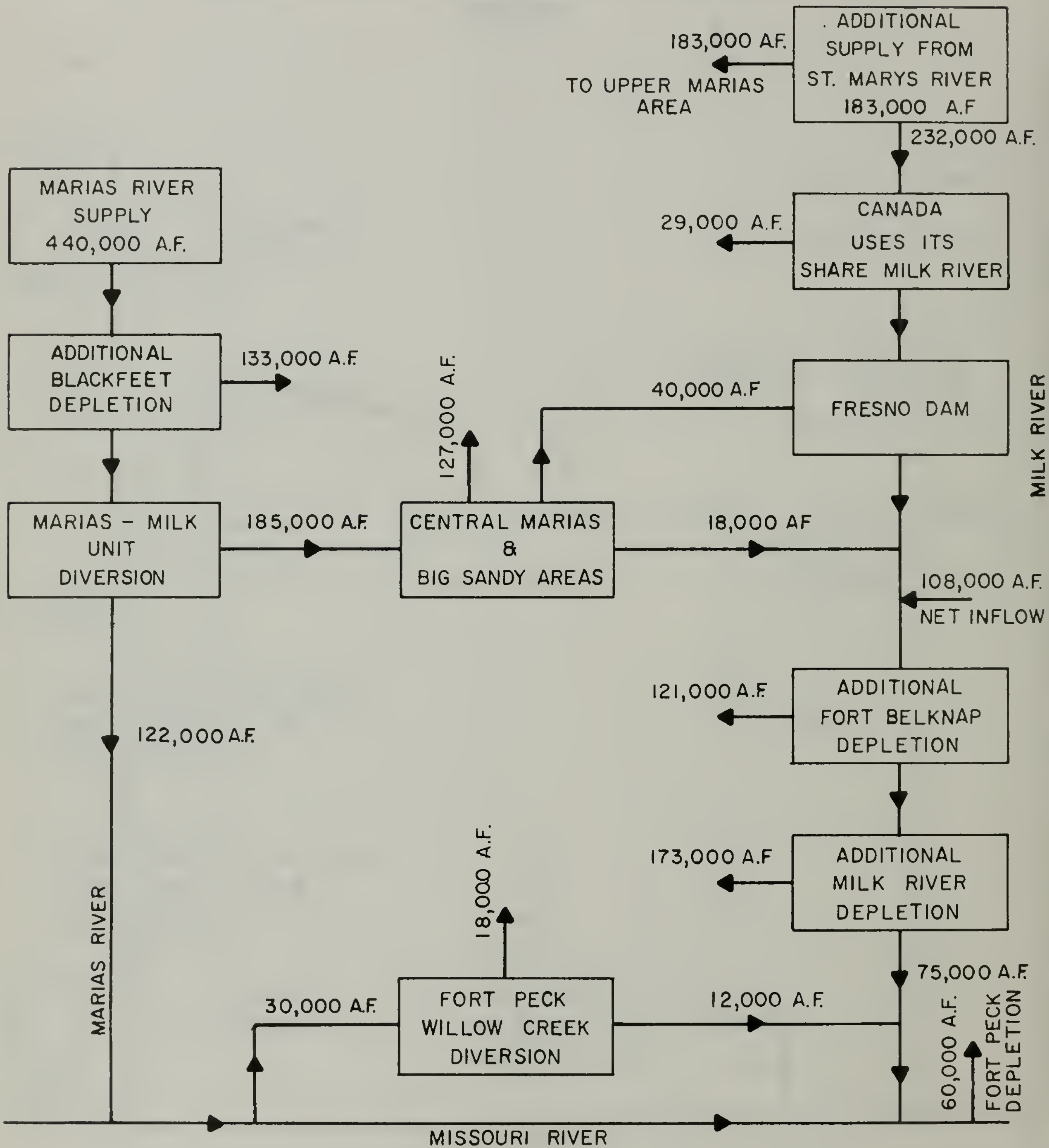
PROPOSED DEVELOPMENT WITH PLAN OF COMPLETION DEVELOPMENT ON INDIAN RESERVATIONS TO 1980



Note: *Supply based on 65 % of average annual flows with existing level of developement.*

FIGURE X - 2

PROPOSED DEVELOPMENT WITH ULTIMATE DEVELOPMENT ON INDIAN RESERVATIONS TO YEAR 2020



Note: *Supplies based on 65 % annual average with existing level of development.*

FIGURE X-3

Figure X-1 shows existing conditions and Figure X-3 shows ultimate development under the Functional Plan including development of the Upper Marias Area.

2. St. Mary River Diversion to the Upper Marias Area. The Upper Marias Area located in Toole and Liberty counties is characterized by an abundance of potentially irrigable land and an absence of adequate surface and ground water supplies. As a result, this area is almost completely dependent on dryland farming. Of the 627,000 acres in Toole and Liberty counties with soils suitable for irrigation development, only 14,000 acres are presently being irrigated.

Landowners in this area have continuously expressed an interest in irrigation, particularly during drought periods. In response to local interest, the USBR has investigated a number of alternate plans for importing water to the area from the Waterton, Belly and St. Mary Rivers.[5]

The plan which appears to be the most feasible for getting water to the Upper Marias Area would consist of the following:

1. Negotiate a trade with Canada to exchange Watertown-Belly flows for additional water from the St. Mary River or, as an alternate, enlarge the existing storage and diversion facilities to divert a larger portion of U. S. share of St. Mary water as established by international agreement.

2. Enlarge the existing St. Mary Canal and construct a new canal which would divert water from the Milk River to a new dam and reservoir on Willow Creek near Devon in Toole County.

3. Construct a distribution system of canals and laterals for supply to lands to be irrigated in the Upper Marias Area.

This plan would provide water for the irrigation of 69,000 acres and would provide a source for municipal and stockwater requirements. The preliminary cost estimate for this plan escalated to 1970 prices is $56,700,000. This estimate includes all of the necessary supply and storage works associated with the project together with the irrigation distribution system. Based on the preliminary studies by the Bureau of Reclamation in 1953, this project could be economically feasible with a benefit-cost ratio of as high as 1.7/1.0.

The study by the USBR was very preliminary in nature, and it is not within the scope of the present study to make an accurate determination of the practicality and feasibility of importing water into the Upper Marias Area; but based on the preliminary findings by the Bureau of Reclamation and on the critical need for a reliable source of good quality water in this area, it is felt that the project should be investigated further.

An interesting possibility also exists in the development of sufficient flood water storage on Milk River tributaries together with the Marias-Milk Unit. It may be feasible to divert part of the water which presently supplies Fresno Reservoir into the Upper Marias Area with the Fresno depletion being made up by the Marias-Milk Unit and new storage sites downstream of Fresno. This would mean that more water could be diverted from the St. Mary River and what wasn't needed below Fresno Dam, considering the additional supplies from the Marias-Milk Unit and storage on tributaries, could be diverted to the storage reservoir on Willow Creek near Devon. Return flows from the Upper Marias Area would enter Tiber Reservoir on the Marias River and would be available for rediversion to the Milk River through the Marias-Milk unit.

As discussed in Part VIII of this report, some of the major impacts from irrigation development are not reflected in a feasibility evaluation expressed solely in monetary terms. The Upper Marias Area, in particular, being dependent on the vagarities of natural precipitation, could benefit immeasurably from the stabilizing effect of irrigation and resulting farm diversification. For this reason, the St. Mary River Diversion to the Upper Marias Area has been included as a project in the present "Functional Plan of Development" with full recognition that many obstacles will have to be overcome before the plan can be fully implemented.

3. Marias-Milk Unit. Under this plan, the Bureau of Reclamation proposes diversion of water from the existing Tiber Reservoir on the Marias River for irrigation of about 72,700 irrigable acres of land now dry-farmed in the Marias and Milk River basins, and to provide a supplemental supply for as much as 122,700 acres of land presently irrigated in the Milk River Valley. Associated with the Marias-Milk Unit is the need to complete modifications of Tiber Dam to restore full flood control and conservation capabilities of the reservoir. Besides irrigation development, completing modifications to Tiber and construction of Marias-Milk Unit would provide for municipal and industrial water, flood control, fish and wildlife enhancement, water quality control, and other conservation purposes.[6]

Planned modifications of Tiber Dam consist of reconstructing the existing spillway structure and raising the dam and dike about 9 feet in elevation.

The 72,700 irrigable acres proposed for irrigation development under the present plan lies within three separate areas: The Central Marias Area, 37,800 acres; the Big Sandy Area, 15,000 acres; and the Milk River Valley Area, 19,900 acres.

The project would require 80 miles of new canal to transport Marias River water from Tiber Dam to Fresno Dam, a distribution system

in the Central Marias Area and a 64 mile branch canal to supply water for irrigation in the Big Sandy Area.

Also included in the present plan for multipurpose development would be the creation of two new waterfowl areas, and the expansion of an existing area. These three areas are located at Lonesome Lake, Chain-of-Lakes Coulee, and the Bowdoin National Wildlife Refuge, and would be used for resting and production of waterfowl. The Lonesome Lake area would receive a portional water supply from the unit and when fully developed would contain approximately 1,600 acres. The Chain-of-Lakes area located adjacent to the west side of Fresno Reservoir, would receive a portion of its water from the Marias-Milk Canal and when developed would contain approximately 8,040 acres. The development plans for expansion of Bowdoin National Wildlife Refuge would consist of importing approximately 10,000 acre-feet of additional water through their existing facilities.

An important part of the Marias-Milk Study was the detailed classification of land to determine the extent, location, and physical and chemical properties of potentially irrigable land. About 168,000 acres were classified. The first and most precise separation of land was into arable and nonarable classes. As indicated earlier in this report, lands which will not support sustained production under irrigation or which would be overly difficult or expensive to drain are not considered suitable for new irrigation development. Many of the areas irrigated under the earlier Milk River Unit would not be considered for irrigation by today's standards.

While the Marias-Milk report has not been finalized at the time of writing of this report, enough information is available to indicate that the total project cost will probably be close to $76,800,000 and the project has been shown to be feasible, both from an economic and engineering point of view.

4. Fort Peck - Willow Creek Diversion. The diversion of water through a gravity channel between the Fort Peck Reservoir and the Willow Creek drainage near Glasgow has been proposed. A very preliminary investigation by the Corps of Engineers and Bureau of Reclamation indicated that the plan may have considerable merit in any future plan for development of land and water resources in the area.[7]

An examination of topographic maps of the area shows that an excavated channel 4 or 5 miles long, with a maximum cut of about 70 feet, would be required to divert water from the normal low water level of Duck Creek arm of Fort Peck Reservoir to the Willow Creek drainage. A suitable control structure would be required to regulate flows.

Under the original proposal the channel would be excavated through the application of explosive techniques. The actual construction method would be determined by economics and there is not enough information to estimate the project cost at this time.

Water from the project would be used to irrigate approximately 10,600 acres in the Glasgow Bench area and could supply supplemental water to portions of the lower Milk River Valley. The topography in the Glasgow Bench would require that a good portion of the irrigation be performed by sprinklers rather than gravity-type irrigation.

5. Irrigation Development on Indian Reservation Lands. The Study Area includes the Blackfeet, Rocky Boy, and Fort Belknap Reservations and part of the Fort Peck Reservation. As indicated earlier, the "Winters Doctrine" and numerous other court cases have firmly established the principle whereby the United States government in establishing reservations set aside not only the land but the water for the use of the Indians.

In helping the tribal councils plan and provide for future water requirements, the Bureau of Indian Affairs has prepared "plan of completion" and "potential irrigation development" reports for each of the reservations. The "potential irrigation development" reports by the BIA considers essentially all areas on the reservation for which any foreeseeable development can be determined and this is the level of development assumed on the Indian lands in the present report.

Under ultimate development, a total of 47 storage projects may be built on reservation land including 24 on the Blackfeet Reservation, 2 on the Rocky Boy Reservation, 15 on the Fort Belknap Reservation and 6 on the Fort Peck Reservation within Valley County.

Most of the land shown as being considered for irrigation development on the Rocky Boy Reservation or associated Indian lands could be serviced from the Big Sandy Canal of the Marias-Milk project and the project on Big Sandy Creek in Chouteau County. Projects on the Fort Peck Reservation, with the exception of the projects on Porcupine Creek, are on streams which drain directly into the Missouri River downstream of the Milk River confluence. Neither the Rocky Boy or Fort Peck Indian projects are expected to have any major impact on water availability to the rest of the Study Area.

Ultimate irrigation development on the Blackfeet and Fort Belknap Reservations, however, could significantly influence water availability in the rest of the area. Based on the "potential irrigation development" report for the Blackfeet Reservation, the ultimate depletion of flow from the Marias River watershed is estimated as 180,400 acre-feet annually. An additional 21,600 acre-feet would come from the Milk River watershed and 1,700 acre-feet would be used from the St. Mary River watershed. Similarly, the ultimate development of irrigation on Fort Belknap land is estimated to require as much as 108,300 acre-feet. These water requirements were considered in this study, except that the model results indicated insufficient flow

available at the structures on the Fort Belknap Reservation during the 65% annual flow design year to meet the 108,300 acre-feet requirement. In this case, the model assigned the available flow to the Fort Belknap projects.

Because the water requirements for ultimate development may never be fully consumed due to economic, physical or population restrictions, the level of development anticipated for 1980 under the "plan of completion" is depicted in Figure X-2. Nevertheless, since development on Indian reservations could limit the amount of water available for development throughout the Study Area in the future, the water requirements for ultimate development of Indian lands has been considered as a basic restraint in this study.

6. Municipal and Rural Water Supply. There are several avenues that may be followed in providing a more dependable, good quality water supply to the rural areas and municipalities of the Study Area. It is imperative that this task be accomplished to meet the increasing domestic demands associated with higher living standards, to provide stockwater demands involved with farm diversification and to promote industrial growth connected with a stabilized economy.

Surface water could be used to enhance some areas within the Study Area. Water from the proposed impoundment structure near Devon in the Upper Marias Unit could supply the areas that are devoid of suitable water in central Liberty and Toole Counties. The Tiber Dam structure in the Lower Marias Unit could supply similar unwatered areas in Lower Liberty County and parts of Chouteau County. Other surface structures in the Study Area may serve as a source of supply for commercial water haulers.

Substantial progress has been made in the field of water demineralizing in recent years. Research and development work by governments and industry have resulted in lowered costs, more efficient processes and a wider applicability of several types of demineralizing plants. These include distillation, electrodialysis, freezing reverse osmosis and ion exchange. One of these processes may herald the use of the highly mineralized waters underlying the Study Area. In most instances, the water requirements for a treatment facility are 100 gpm or less. Many types of package-type water treatment facilities are being produced today. A reverse osmosis operation package plant having a capacity of 70 gpm would cost approximately $155,000 with operating costs of approximately $0.75 per 1000 gallons for the treatment plant alone. This does not include well and storage costs. Operating data for distillation type processes show a definite trend toward reduced costs. Hopefully the combined efforts of scientists, engineers, technicians and plant operators will lead to an economical solution to the treatment of the mineralized ground waters found in this area and these principles will be applied to do great benefit in the future.

Consideration should be given to the creation of rural water districts where farms are close enough together. Presently, most rural farms are too far apart to make rural water systems economically feasible. In the midwest, the requirement of two customers per mile is needed to justify the economics of the rural water system; however each particular area would have to be considered on its own economic merits. Where water is presently being hauled for long distances, it may prove feasible for the farmers and ranchers to construct an expensive system in lieu of paying high hauling costs. Another consideration may be the formation of commercial water hauling from either a surface supply source or in the future from a demineralized ground water source. Commercial hauling would provide for improved sanitary conditions in the handling of the water and would appear to be less costly than having each individual farmer and rancher hauling his own supply.

For this report, economic evaluations have not been made. Further study will be necessary to determine the avenue or avenues which should be pursued to bring a suitable water supply to the entire area of study. The creation of a Conservancy District would provide the coordinated effort to accomplish the task of providing a dependable, good quality water supply.

7. Flood and Erosion Control. Flood damage throughout much of the Study Area is limited to agricultural crop damage and as such single purpose flood control projects can rarely be justified. There are, however, flood control benefits associated with any storage project because of peak attenuation and flood control which should be considered as a project function anywhere that flood damages are experienced.

Three watershed protection and flood control projects which have been investigated and reported on by the SCS in the area were considered in this preliminary study. These are the City of Browning Watershed Project, the City of Shelby Watershed Project, and the Beaver Creek Watershed Plan. The Beaver Creek Project in Hill County has already been discussed in Section B-1 of Part X.

The City of Browning watershed plan calls for two single purpose floodwater retarding structures and channel improvement on Willow Creek through Browning. One dam is planned on Willow Creek and another at Goose Lake, both upstream of Browning. These two dams would control runoff from 20.4 square miles or 69 percent of the drainage area that contributes floodwater to Browning. The dam proposed for Willow Creek would be designed for 1,527 acre-feet of floodwater storage and 92 acre-feet of sediment storage. The dam would be 46 feet high and contain 107,300 cubic yards of earth fill. The proposed dam at Goose Lake would enlarge the capacity of the existing natural lake to provide 308 acre-feet of floodwater storage and 19 acre-feet of sediment storage. This dam will be 15 feet high

and contain 29,700 cubic yards of earth fill. In addition, the channel of Willow Creek will be straightened and enlarged. The combined effect of the two floodwater retarding structures and channel improvement will provide the city with a 100-year level of flood protection. The installation costs were estimated at $172,400 for the two dams and $8,000 for the channel improvement (1969 prices). An additional $10,000 is estimated for land treatment measures. Amortization of $198,300 total project cost at 5 1/8 percent for 100 years amounts to $10,200. The average annual operation and maintenance costs are estimated at $700 for the reservoirs and $100 for the channel. Total average annual costs are estimated at $11,000 Total annual benefits stemming from the elimination of floodwater and sediment damages to residences, city streets and roads, and local businesses are estimated at $26,500. Of the total $198,300 estimated cost, $184,200 would come from PL-566 funds.

The City of Shelby watershed Plan, completed in 1969, includes a floodwater retarding and recreational dam, recreational use facilities, and a diversion channel above the residential area of Shelby. The latter intercepts runoff from an area within the watershed which is not controlled by the retarding structure. The reservoir provides storage capacities of 1,035 acre-feet for floodwater detention, 344 acre-feet for recreational water, and 151 acre-feet for sediment. The average annual benefits from flood protection are estimated at $81,661. The average annual benefits from recreation were originally estimated at $11,550 but use of recreational facilities has been greater than anticipated and consideration is being given to expanding the recreational facilities in the near future.

In addition, there are 8 watersheds for which applications have been approved, but reports have not yet been written. These watersheds and the SCS status as of January 10, 1969 are:

Watershed	County	Date Application Approved	Status
1. Cottonwood Creek	Liberty	2/16/55	Preliminary investigations completed. Planning terminated due to lack of feasibility. Renewed interest in 1968 after Morrison-Maierle report. Change in P. L. 566 Law and SCS policies require further study on feasibility.
2. Pondera Creek	Pondera & Teton	2/16/55	Planning terminated - failure to acquire reservoir site.

Watershed	County	Date Application Approved	Status
3. Thirty Mile	Blaine	6/18/57	Preliminary investigations made. Project infeasible with flood detention structures - probably feasible with channel improvement, depending upon local action.
4. Fort Belknap	Blaine	6/21/61	Unserviced because of loss of local interest.
5. Paradise	Blaine	6/21/61	Unserviced - lack of local interest.
6. Birch Creek	Pondera & Teton	6/19/64	Unserviced - storage reservoir rebuilt by Bureau of Reclamation.
7. Highwood Creek	Chouteau	6/29/65	Preliminary investigations completed. Further development depends upon local interest.
8. Willow Creek	Valley	2/15/66	Unserviced.

The Corps of Engineers presently is studying two flood control projects in the area. One concerns the low-lying residential areas and sanitation lagoon of Nashua which are subject to flooding from the Milk River and Porcupine Creek. A preliminary study to determine the feasibility of providing the needed flood-control protection should be completed in the near future. The other concerns the northern section of Malta which is threatened by periodic flooding from the Milk River as a result of spring snowmelt and rainfall. Damage from flooding has occurred on an average of once in 10 years. Preliminary studies indicate that the needed protection can be provided by a levee. A detailed project report is forthcoming.

The Corps of Engineers has also started a review of a previous report on Marias River flood control to determine if additional works are necessary on the River in light of the 1964 flood. This report is not scheduled to be completed until 1974.

In some areas, particularly along the Milk River in Blaine County, bank erosion has been a problem. The studies that have been made indicate that seepage forces associated with irrigation return flows have been the prime cause.[8] Necessary drainage or other measures could be effectively handled under the framework of a Conservancy District.

8. Drainage and Mosquito Control. The Study Area, particularly the Milk River Valley, has a serious problem with mosquitoes. The concensus of those who have studied the problem is that mosquitos thrive in the area because of excessive use of irrigation water and inadequate drainage facilities. Anywhere water is allowed to pond for any length of time becomes a breeding ground for mosquitoes. Some areas, such as Glasgow, have attempted to alleviate the problem by carrying out a program of spraying. The real problem, however, the standing water continues to supply mosquitoes. Phillips County, since 1963, has had a Mosquito Control Board which is making progress on the problem in that area, but more needs to be done. This summer, for example, mosquitoes trapped and tested under a program by the Phillips County Mosquito Control Board were found to be infected with encephalitis or sleeping sickness; others were the species of mosquito which carries malaria, but none of the ones tested were actually infected.

The entire Milk River Valley, and other areas where mosquitoes are a problem, should be surveyed and a drainage program initiated to eliminate the breeding areas. Since drainage is one of the functions of a Conservancy District under Montana law, a Conservancy District would be the logical body for implementing a comprehensive area-wide mosquito control program.

9. Water Master Program. Specific benefits would accrue to all water users within the proposed Conservancy District if the available waters were properly managed and their distribution, diversion and return to the parent stream specifically controlled by a single agency such as would be the case under a Conservancy District administrative organization. In other areas such as in the Greater Central Valley and also the Imperial Valley of California where water is also scarce and therefore valuable, the administration of the distribution of the available waters by a master agency has, in every case, resulted in a greater apparent availability of water for all needs.

The technique involved here, in general, is that all water demands to be made on a given source must be pre-scheduled in time and pre-determined in amount such that the known available resource is never taxed beyond its ability to supply. Without this type of control, situations could develop where a majority of the diversion from the source may occur within a single day with the obvious result that the stream will appear to be overcommitted. Yet for the next several days following this short day, the stream will appear to have quite adequate flows. If the diversion had been programmed and pre-scheduled such that they were distributed both in quantity and time, the results would be that all needs could be met, the stream would not be depleted, and greater productive and beneficial uses of the water could be realized.

The development of a Water Master Program throughout the Conservancy District would take time and the cooperation of the various users,

that is the water-rights holders throughout the area. In terms of pre-feasibility evaluations, it is sufficient to say that substantial benefits to all water interests within the Conservancy District could be expected through the implementation of a coordinated Water Master Program.

10. Fish, Wildlife and Recreation. The water related sports will all benefit from the projects as proposed in the project plan. Boating, water skiing, fishing, hunting and sailing are some of the sports that will benefit from the projects proposed herein. As an example of the benefits to wildlife in the area, the chain of lakes development as part of the Marias-Milk unit will provide a habitat for waterfowl where none has existed before. In a proposal for the UL Bend National Wildlife Refuge, the Bureau of Sport Fish and Wildlife would pump water from Fort Peck Reservoir to establish and maintain a nesting area for waterfowl. Additional habitat would be provided for plains animals and small game. When the Tiber reservoir was constructed, the lower portion of the Marias River became an excellent trout stream whereas before the construction, silt carried from the headwaters of the stream had made the Marias a very turbid river not suited for trout. Many of the projects provide an excellent opportunity for the development of camping areas as well as fishing and hunting areas.

C. PROJECT PRIORITIES

It is difficult to assign project priorities at this stage of study. Nevertheless, if energies and monies are to be most effectively spent on more detailed studies, the preliminary studies should form a basis for deciding which projects should be studied further. A problem here of course is that while the study has been conducted from a broad overall point-of-view considering only gross aspects, the people most interested in the report are invariably familiar with minute details of one or two particular projects. It is very difficult to prove one project should be of a higher priority based on general, broad information when a proponent of another project is ready, willing and able to give detailed information about why his project is more beneficial. It is not the purpose of this report to generate new data on potential projects and only those projects for which a report has been written are considered in detail. Because of the preliminary nature of this survey, priorities can only be used as a guide which should be updated and revised as more information becomes available.

Perhaps the number one priority should be development of a water supply source in the Upper Marias Area because of the almost complete lack of good water supply in this area, even for drinking water. As already pointed out, however, the source which would appear to be the most feasible for the Upper Marias Area, the Milk and St. Mary Rivers, is currently being used for irrigation in the Lower Milk area.

For this reason, it is felt that providing additional storage on major tributaries to the Milk River together with the Marias-Milk Unit should probably be given first priority. As more water is made available to the Lower Milk area through storage of flood water from tributaries and trans-basin shipment from the Marias River, the water requirements in the Milk River Valley can be met without relying on all of the 232,000 acre-feet which currently flows into Fresno Reservoir. The difference combined with additional water from the St. Mary River or Waterton-Belly area could provide a significant amount for development of the Upper Marias Area. Providing there is local interest from residents of the Upper Marias Area, studies should be initiated to determine the amount of water that can be made available from the St. Mary-Waterton-Belly area considering physical and political limitations.

As far as priorities for developing storage sites along the Milk River, ideal sites on the larger upstream tributaries should be developed first as these would provide the largest measure of control to the largest portion of the irrigated lands. In practice, local interest, stage of planning and availability of federal funds for the various projects will determine which projects are constructed and the order in which they are built. The same can be said for all of the other projects in the Study Area such as the Dry Fork project in Pondera County or the Fort Peck-Willow Creek project in Valley County.

Municipal and rural water supply and flood control projects do not consumptively use large quantities of water and thus do not require coordinated area-wide planning to the same extent as irrigation projects. Building a floodwater retarding structure at Shelby, for example, does not materially change the total supply downstream, but does smooth out the flows. For this reason, domestic water supply and flood control projects should be built on the basis of need without waiting until several similar projects have been completed in other areas.

All of the municipal and rural water supply projects and flood control projects discussed in this report should be pursued subject only to the limitations of local interest, completeness of planning, and availability of funds.

Development of water resources projects on Indian lands should proceed in accordance with the needs of the Indians.

Other elements of the functional plan, such as "Drainage and Mosquito Control," "Water Master Plan," and "Fish, Wildlife and Recreation," could be integrated into the functions of the Conservancy District, if and when it is formed.

FOOTNOTES - PART X

[1] The water quality control requirement of 122,400 A. F. is from the "Marias-Milk Unit, Field Draft of Report, Copy 12, U. S. Bureau of Reclamation, March 1970," p. 67. At the writing of this report, the Marias-Milk Report had not been released. Material in this report is based on information in the above preliminary draft.

[2] U. S. share of St. Mary River flow (271,000 A. F.) minus 149,000 A. F. currently being diverted for use within the U. S.

[3] In this case, the only information available is that contained in the State Water Conservation Board Potential Project Report, January 1965, and in the MWRB files on Potential Projects.

[4] See references X-11, X-12, X-13, and X-14 in the Bibliography.

[5] See reference X-6 in the Bibliography and also "Second Interim Report on the All-American Tunnel and Canal Route," USBR, Billings, 1950 and "Study of Possible Plans Pursuant to the May 18, 1950 Minutes of the International Joint Commission" by the U. S. Section of the International Waterton-Belly Rivers Engineering Board, April 1951.

[6] This statement based on a preliminary draft of the Marias-Milk Project Report, see reference X-7.

[7] A formal report on this project has not been prepared, for current status see references X-8 and X-9.

[8] Based on discussions with USBR personnel familiar with the bank erosion problem along the Milk River.

PART XI - FINANCIAL ASPECTS

PART XI

FINANCIAL ASPECTS

A. GENERAL. The proposed Water Conservancy District Law provides for financing from a 2 mill levy on the taxable real property within the proposed District Boundary to be used for administration of the District and 3 mills for retirement of bonds and other debts. The nine county Study Area has a taxable valuation on real property of $34,652,884.[1]

B. REVENUE. 2 mills would provide $69,306 annually for administration and operation of a district covering the entire nine county area and 3 mills would provide $103,959 annually for debt service over the same area.

The 1968 assessed and taxable value of real property for each of the counties in the Study Area are as follows:

County	Assessed Value[2]	Taxable Value[3]
Blaine	$ 9,147,004	$ 2,744,101
Chouteau	24,979,055	7,493,716
Glacier	7,680,156	2,304,047
Hill	16,786,575	5,035,972
Liberty	8,479,088	2,543,726
Phillips	9,835,722	2,950,717
Pondera	12,954,986	3,886,496
Toole	13,099,329	3,929,799
Valley	12,547,698	3,764,309
Total	$115,509,613	$ 34,652,884

C. FEDERAL FINANCING. Most of the potential projects as listed herein are Federally financed with the actual people who benefit from the use of the water paying back the investment over a long period, usually 100 years. The interest rate charged by the U.S.B.R. is currently 5 1/8%.[4] When this attractive rate is coupled with a 100 year payout period, the annual charge for debt reduction is small and may not have to be charged against the Conservancy District debt reduction budget. There are many Federally financed programs available for Water Development Projects. Any such financing would reduce the burden on a Conservancy District's debt reduction budget. Some of the programs to finance Water Development Projects are:

1. Agricultural Stabilization and Conservation Service.[5] The agricultural conservation program (ACP) is one of the programs administered by the Agricultural Stabilization and Conservation Service (ASCS). ACP provides financial assistance to farmers and ranchers in the form of cost-sharing to install conservation measures

Numbers refer to footnotes located at the end of this chapter.

on their land. Participation in the program is voluntary. Assistance is offered to protect, improve and renew soil, water, woodland, and wildlife resources. Having adequate vegetative cover on the land also helps to protect the water resource. Listed below are the cost-sharing practices offered in the ACP in Montana which are considered to be directly related to water management.

B-5 - Constructing wells for livestock water.

B-6 - Developing springs or seeps for livestock water.

B-7 - Constructing dams, pits or ponds to provide water for agricultural uses.

B-8 - Installing pipelines and artificial watersheds for livestock water.

C-1 - Establishing sod waterways to dispose of excess water.

C-5 - Constructing diversion terraces, ditches or dikes to intercept runoff and divert excess water to protected outlets.

C-5 - Constructing erosion control, detention or sediment retention dams.

C-7 - Constructing channel lining, drop spillways and similar structures that dispose of excess water.

C-8 - Installing rock riprap, jetties, levees, dikes and other measures to prevent erosion and flood damage to farmland.

C-9 - Constructing permanent open ditches for ground and surface water.

C-10-Installing underground water control systems for ground and surface water control.

C-11-Shaping or land grading to permit effective surface drainage.

C-12-Installing or reorganizing irrigation systems.

C-13-Leveling land for more efficient use of irrigation water.

C-15-Lining irrigation ditches to prevent seepage and erosion.

C-16-Constructing spreader ditches or dikes to spread runoff water on rangeland.

G-2 - Development or restoration of shallow water areas for wildlife.

G-3 - Constructing ponds or dams for wildlife.

G-4 - Fencing of streambanks for the benefit of wildlife and to prevent erosion.

The amount of cost-sharing provided on these conservation measures varies from 50 percent to 80 percent of the average cost.

2. Farmers Home Administration.[5] The Farmers Home Administration has been authorized to provide grant assistance to local public bodies to finance comprehensive area plans for water and sewer systems. The minimum area to be included in each comprehensive area plan is the rural area of each county. The purpose of the plans are to promote efficient and orderly development of rural communities and to provide information necessary to avoid overlapping, duplication, underdesign, or overdesign of community water and sewer facilities.

3. Forest Service.[5] The U. S. Forest Service water-resource activities fall under seven broad categories as follows:

a. Watershed Surveys and Plans.

b. Watershed Protection and Management.

c. Hydrologic Surveys, Prescriptions and Plans.

d. Water Use - Quantity and Quality.

e. Soil Surveys, Interpretations and Management.

f. Watershed Cooperation.

g. Impacts and Liaison - Out-Service Water-Oriented Development Projects.

4. Soil Conservation Service.[5] The Soil Conservation Service is the technical soil and water conservation agency of the U. S. Department of Agriculture (USDA). It is responsible for developing and carrying out a national program of conservation for land and water resources.

The Soil Conservation Service (SCS) administers USDA activities involving technical assistance in soil and water conservation and technical and financial assistance for planning and executing programs to protect and improve water and related land resources in small watersheds.

Watershed protection and flood prevention work combines soil and water conservation on the land with control and use of runoff by means of upstream structures. This work is authorized by the Omnibus Flood Control Act of 1936 (Public Law 738, 74th Cong), the Flood Control Act of 1944 (Public Law 534, 78th Cong.), and the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Cong. as amended.)

SCS has administrative leadership for Federal assistance to local organizations for planning and carrying out small watershed projects under the Watershed Protection and Flood Prevention Act. (Public Law 566). This Act provides for technical and financial assistance by USDA to State or other local organizations for land treatment, flood prevention, irrigation, drainage, public recreational or fish and wildlife developments, and municipal or industrial water supplies on watersheds up to 250,000 acres in size.

USDA contribution to these projects is of three types:

a. Technical assistance in planning, designing, and installing works of improvements;

b. Sharing costs of flood prevention and agricultural water management, public recreation or fish and wildlife development; and

c. Extending long-term credit to help local interests with their share of the costs, including costs of developing industrial or municipal water supplies.

These projects are planned for integrated use and conservation of all water and related land resources in a watershed.

Structural measures can be of three kinds:

a. Flood prevention measures - which are eligible for Federal assistance for the full cost of construction and engineering;

b. agriculatural water management measures, such as drainage and irrigation, or provision of a more uniform supply of water for agricultural use, and public recreation or fish and wildlife developments - which are eligible for Federal technical assistance and cost sharing; and

c. non-agricultural water management measures such as municipal or industrial water supplies and stream regulation- for which local interests pay the full cost. Loans or advances may

be obtained from USDA under certain conditions to help local organizations pay their share of the costs.

Small watershed projects are initiated by local organizations having authority to carry out, operate, and maintain works of improvements under Public Law 566 as amended. Qualified organizations are defined by law and may be a State or any instrumentality thereof. These include soil and water conservation districts, watershed, conservancy, drainage, irrigation or other special purpose districts, water users' associations, municipalities, and similar organizations not operated for profit.

5. Bureau of Indian Affairs.[5] This agency provides programs and financing for Water related projects on the Indian Reservations. The programs which would be available to others would also be available to the Indians for financial assistance.

Principal Indian Irrigation Projects include the Fort Peck project which has been approved, and the Fort Belknap and Blackfeet Projects which are pending final approval.

6. Bureau of Land Management.[5] The Bureau's soil and watershed program for public domain lands includes evaluation of watershed conditions and the installation and maintenance of watershed treatment practices to retard erosion and reduce peak discharges. Among treatments commonly used are detention dams, contour furrowing, and development of increased vegetative cover through management of surface use.

Objectives of the program include (1) the enhancement of off-site values and water quality by reducing sediment runoff, flood damage and siltation, regulating stream flow, and replenishing underground water supplies, and (2) the enhancement of on-site values by restoring and protecting soil resources for current and future use.

7. Bureau of Outdoor Recreation.[5] The Bureau of Outdoor Recreation conducted a recreation-oriented study of the middle Missouri River from Yankton, South Dakota to Fort Benton, Montana. The authority of this study was a Senate Committee on Interior and Insular Affairs resolution adopted on February 17, 1966. The field phase of this study was conducted by the Bureau's Mid-Continent and Pacific Northwest Regional Offices. A report on the Bureau's findings and recommendations was released on June 18, 1968, andis entitled, "The Middle Missouri . . . A Rediscovery." One of the major recommendations contained in the report refers to the establishment of a Missouri Breaks National River extending from Coal Banks Landing, Montana to the western boundary of the Charles M. Russell National Wildlife Range, Montana.

The Mid-Continent Region is now conducting a recreation reconnaissance study of the proposed Bureau of Reclamation Moorhead Reservoir Project, which would be located on the Powder River in Montana and Wyoming. The report will contain recommendations that recreation be considered as a project purpose, that recreation development be cost-shared by Federal and non-Federal interests under provisions of P. L. 89-72, the Federal Water Project Recreation Act, and that a more detailed recreation study be conducted if Congress authorizes a "feasibility" report.

The source of the Bureau of Outdoor Recreation funding for most water resource planning work in Montana is the Missouri River Basin Project Fund.

8. Federal Water Pollution Control Administration.[5] U.S. Public Law 660 provides construction grants to communities for the construction of Water Pollution Control Facilities. This is administered by the FWPCA.

9. Bureau of Reclamation, Regional Office, Region 6,[5] Billings. All appropriations for programs are made through the Public Works Appropriation Act except parts of programs which are financed from advances by the water users or from contributed funds.

New reconnaissance, basin survey, and feasibility investigations are requested from time to time by potential water users. An investigation is scheduled when budgetary considerations permit their inclusion in the planning program and requests are made to the Congress for funding. Specific authorization by the Congress of a feasibility investigation is required under present legislation.

Following authorization of a unit and execution of necessary repayment contracts covering the reimbursable costs, requests for construction funds are made to the Congress and upon approval, construction is initiated.

The outlook for new construction in the area will depend on budgetary considerations, authorization of units, and the support of the prospective water users.

10. Corps of Engineers.[6] The Corps of Engineers, U.S. Army, has broad authorities and responsibilities in the field of water resources development. Primary concerns are flood control and navigation. However, where either flood control or navigation are primary purposes of a project other features of water resources development may be included. Such features include hydroelectric power, irrigation, domestic and industrial water supply, recreation, fish and wildlife conservation, and water pollution abatement. The Corps also has authority and responsibility to assist local interests in the event of a flood

emergency that is greater than can be handled with local resources.

Requests for Corps of Engineers' services for water resources development may be addressed to the Congressman or District Engineer who serves the area where the service is desired. In either case, the request will follow the route necessary to determine an appropriate answer. The larger projects require specific approval by the Congress after a detailed investigation of feasibility by the Corps of Engineers. Certain smaller projects may be constructed without the specific approval of the Congress after an appropriate feasibility study within the Corps of Engineers.

Secretary of the Army may allot not to exceed $25,000,000 for any one fiscal year for the construction of small projects for flood control and related purposes; not specifically authorized by Congress; not more than $1,000,000 to be spent at a single locality. Expenditure of funds is prohibited until local interests assure that they will (a) provide lands; (b) hold and save U.S. free from damages; and (c) maintain works other than dams.

The Corps of Engineers is authorized to compile and disseminate information on floods and flood damages, including identification of areas subject to inundation by floods, and general criteria for guidance in use of flood plain areas; and to provide engineering advice to local interests for their use in planning to ameliorate the flood hazard. For specific localities, surveys may be made and information and advise provided only upon request of State or responsible local governmental agency and upon approval by Chief of Engineers.

The Corps of Engineers also has limited funds available for emergency bank-protection works to prevent flood damage to highways, bridge approaches and public works; for clearing and straightening channels, and removing snags in navigable streams and tributaries in interests of flood control, and in flood fighting and rescue operations, or in the repair or restoration of any flood-control work threatened or destroyed by flood, including the strengthening, raising, extending, or other modifications thereof as may be necessary for the adequate functioning of the work for flood control.

In the preceding paragraphs, some of the programs and agencies which may be sources of Federal financing have been outlined. It is, however, not possible at this time to estimate which of these sources of Federal funds would be available for development of conservancy district projects in the next five or ten years. During this time, new programs may be initiated and existing ones may be modified or dropped. Possible sources of financing will have to be given careful consideration during the planning of each individual project.

D. BOND FINANCING. Because the potential volume of construction and financing for an area the size of the proposed North Central Conservancy District would be large, no doubt a substantial part of it would be done by Federal agencies. Nevertheless, it might be necessary for such a district to raise a portion of the cost from local sources. To investigate the practical possibility of local bond financing, Bond Counsel in the person of Mr. Arthur Whitney of the law firm: Dorsey, Marquart, Windhorst, West & Halladay in Minneapolis, have been retained to render an opinion on the practicality of this type of financing.

Some of the important points contained in their opinion are summarized below.

1. "It is apparently the intent of the law that so far as possible the annual cost of operation, maintenance, replacement, depreciation and payment of principal and interest on debt incurred for all conservancy district works should be paid from rates, fees and other charges for the services, facilities and water furnished by the District under Section 89-3414(17)."

2. "Bonds payable exclusively from special assessments or exclusively from utility revenues can be sold to finance facilities------although the history of this kind of financing is almost uniformly unfavorable."

3. ". . . . .it seems inevitable that a guaranty would have to be provided at the state level. Under Title 89, Chapter 1 the Montana Water Resources Board has power to issue revenue bonds for various purposes, apparently including most or all of those that would be authorized for a conservancy district."

4. "Section 89-109 limits the interest rate to 6% per annum and makes the bonds payable exclusively from revenues pledged to a special fund. Under present law, therefore, such bonds would presumably be no more salable than district bonds if issued for the same kinds of projects. However, if financing were negotiated by a state agency such as the Water Resources Board, it would become possible . . . . . to make the bonds just as salable, perhaps even under present market conditions, as the Long Range Building Program Bonds which have been issued in recent years by the State Board of Examiners to finance state buildings and classroom buildings at state educational institutions."

5. "It would perhaps be possible, to some extent, to cut down the total amount of borrowing at the state level by local financing of particular projects, or parts of them, that were economically viable by themselves. Or it might be that individual counties or cities might wish to vote general obligation bonds, in lieu of water revenue bonds or assessment bonds, for their share of some projects. Borrowing by individual conservancy districts might also be practical after a history of production of revenues sufficient for debt service is established."

FOOTNOTES - PART XI

[1] Thirty percent of the total assessed value of real property (less improvements) in the nine counties.

[2] See page 51 of Twenty-third Biennial Report of the Montana State Board of Equalization for the period July 1, 1966 to June 30, 1968.

[3] Thirty percent of assessed value.

[4] The interest rate to be used in plan formulation and evaluation for projects competing for federal monies is based on the average rate of interest payable by the Treasury on interest-bearing marketable securities and this figure is updated annually. The figure thus established and used by Federal agencies at the time of writing this report was 5 1/8%.

[5] The most complete and up-to-date summary of programs and financial assistance in water resources work by State and Federal agencies is contained in Inventory Series Report No. 2 by Montana Water Resources Board released in December 1969. This report contains a summary and preliminary analysis of responses to a request for a description of the nature, scope, and cost involved in the programs conducted by the agencies. Additional information on the programs of each agency is contained in Inventory Series Report No. 2 and in the files of the Montana Water Resources Board. These programs are continually changing and new programs are being introduced. It is therefore imperative that current sources of funds and assistance be investigated as a part of evaluating the economic feasibility of individual projects.

[6] A summary of programs by the Corps of Engineers is contained in "Water Resources Development by the U. S. Army Corps of Engineers in Montana," January 1969.

PART XII

PROPOSED CONSERVANCY DISTRICT BOUNDARY

PART XII

PROPOSED CONSERVANCY DISTRICT BOUNDARY

Under Montana's water conservancy law, the applicants who request a preliminary survey for a proposed conservancy district are required to generally describe the proposed boundaries of the district. In the present case, the Montana Water Resources Board initially received a request for the formation of a conservancy district to include all or parts of Valley, Phillips, Blaine, Hill, Chouteau, Liberty and Toole Counties. After the initial request had been approved, two additional counties, Pondera and Glacier, requested to be included in the study bringing the total number of counties in the Study Area to nine.

One of the purposes of this preliminary survey as indicated in Section 5, Chapter 100, Montana Session Laws 1969 is to adjust the boundaries of the proposed district to improve the feasibility, desirability or consistency with the state water plan. After the preliminary survey report has been submitted and after a hearing, the water board can, if so requested, prepare a detailed feasibility study of the proposed district. The detailed feasibility report will describe the proposed works and contain an estimate of the costs of the works, the means of financing, and the estimated costs of operation and maintenance. The water board may, based on the detailed feasibility study, further adjust the boundaries in such a way as to exclude land which would receive no direct or indirect benefits. Following the detailed feasibility study, formation of the district will be submitted to a vote. In order for the district to be organized, fifty-one percent (51%) or more of the eligible electors in the proposed district must vote in the election, and a majority of those voting must vote in favor of organization.

The proposed Northcentral Conservancy District Study Area includes all of the Milk and St. Mary River drainage basins within the United States, most of the Marias River basin, and part of the Missouri and Teton River basins. As a result of the review and preliminary analysis of available information, it can be concluded that:

1. There is additional water available for development in the Study Area in limited amounts.

2. Based on reconnaissance surveys throughout the area and detailed soil studies in limited areas, there is more irrigable land than water for irrigation development in the nine counties.

3. Many of the functions of a conservancy district - such as municipal and rural water supply, drainage and mosquito control, coordinated water management - would benefit the area.

4. Water development would be an economic stimulant to the area and may be what is necessary to reverse the trend of declining population.

5. The water resources of the Study Area are limited and a planned, coordinated effort will be required if the available water is to be put to the most beneficial use.

6. Recent trends in the awarding of Federal funds indicate that projects which are part of a coordinated, area-wide plan are favored.

Based on these findings, it can tentatively be concluded that the proposed district is feasible from an engineering viewpoint. Furthermore, all indications from this preliminary survey are that the district would probably be economically feasible and would provide significant benefits to the area.

Since the generation of new data and field testing procedures were not a part of this preliminary survey, many assumptions have been necessary. Detailed feasibility studies will, of course, be required to test the correctness of these assumptions and, in many cases, basic data will have to be generated before the final decision as to feasibility and desirability of the proposed district can be made.

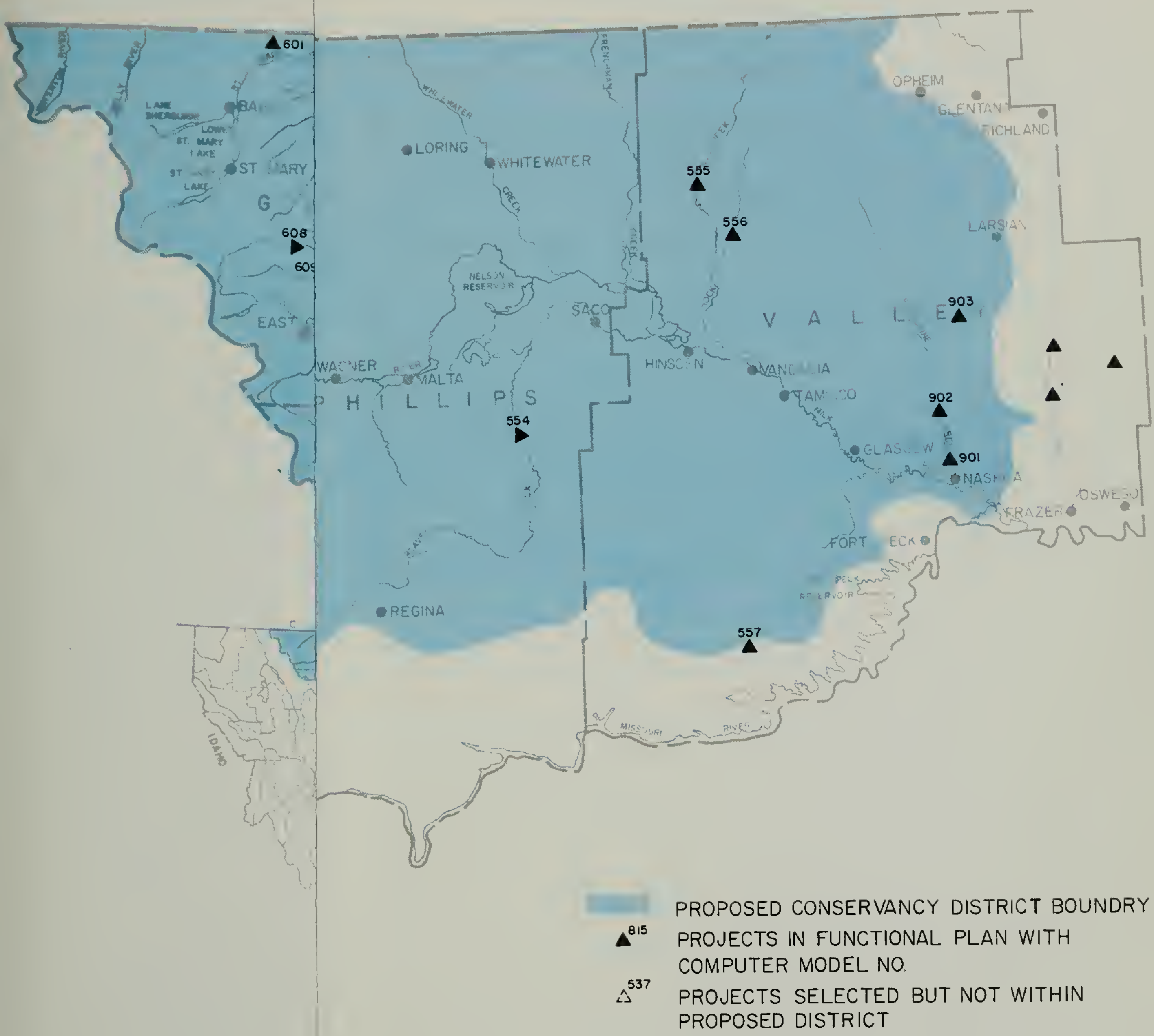
Considering the type of projects anticipated under a conservancy district and the benefits which would accrue from these projects, it would seem that drainage basins would form an appropriate criterion for establishing the boundaries of the district. By following drainage basin lines, areas remote from the irrigated river valleys would be held to a minimum and as other districts are formed, all lands would clearly be in or out of a particular district. However the final boundary lines are selected, the majority of the funds required for the operation of the district will come from the water users directly benefited as is clearly the intent of the law. To the extent that anticipated revenues from rates, fees, and other charges to the water users will not be sufficient to meet the district's obligations for operation, maintenance, and replacement of works, or for payment of interest and principal on bonded indebtedness, the directors may make an assessment of not more than five (5) mills on taxable real property in the district.

The U. S. portions of the Milk and St. Mary watersheds would be entirely within the Northcentral District. The Marias watershed would logically be included in the district also, particularly if plans to provide water to the Upper Marias Area and the Marias-Milk Project are to be given further consideration. It is recommended that further studies of the proposed district include all of the Marias drainage basin which would include an additional strip along northern Teton County.

Since none of the potential projects considered in this study are on or along the Teton River, the benefits to residents of the Teton watershed probably would not warrant their inclusion in this district. The two large projects on the Missouri River, Fort Benton and High Cow Creek projects, would provide recreational benefits to the area, but feasibility of these projects is dependent on power generation which is not a conservancy district function. The

other project along the Missouri, Highwood Creek project in Chouteau County, is too far removed from the rest of the area to be included.

The proposed conservancy district boundary and the projects in the functional plan are shown in Figure XII-1. The numbers next to the triangles are the computer model numbers of the projects which can be used to locate a particular project in the computer model or summary of potential projects in the Appendix.


601
ST MARY
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EAST
LORING
WHITEWATER
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FRENCHMAN
NELSON RESERVOIR
SACO
WAGNER
MALTA
PHILLIPS
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REGINA
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OPHEIM
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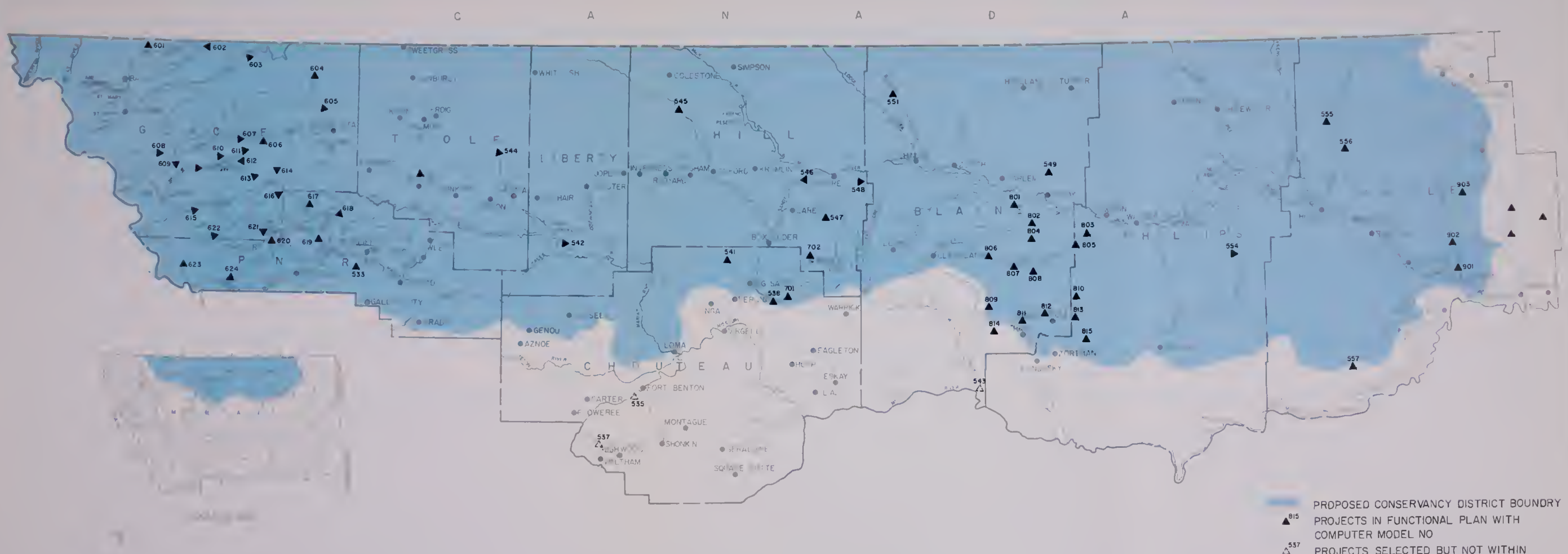
MISSOURI RIVER
IDAHO
PROPOSED CONSERVANCY DISTRICT BOUNDRY
815 PROJECTS IN FUNCTIONAL PLAN WITH COMPUTER MODEL NO.
537 PROJECTS SELECTED BUT NOT WITHIN PROPOSED DISTRICT



CONSERVANCY DISTRICT BOUNDRY AND PROPOSED PROJECTS

FIGURE XII - I

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PART XIII - BIBLIOGRAPHY

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VII-8 Water Well & Spring Inventory for Liberty County, Montana Bureau of Mines and Geology, 1969

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APPENDIX A - OPTIMIZATION MODEL

APPENDIX A

OPTIMIZATION MODEL

A. THE GENERAL OPTIMIZATION MODEL. Linera programming has been chosen for this study as the mathematical technique by which an optimization model is produced. In order to formulate an open-channel flow problem for linear programming, it is necessary to begin with a system description followed by a data identification. The succeeding paragraphs describe these initial phases of model development. The final phases of the model development, also described in succeeding paragraphs, deal with formulation of the system objective functions and constraint functions.

It is the intention of this portion, Part A, of this Appendix to provide the reader with a comprehensive technique enabling him to develop a mathematical model for any given open-channel flow problem. The material provided in Part B illustrates the development and operation of such a mathematical model for an example case.

1. System Description. An open-channel flow system such as that associated with the conservancy district is a network assembled from two basic types of components: nodes and branches. A branch, for the purposes of this discussion, connects any two nodes for flows in a specified direction. Thus, a network so defined containing NN nodes can contain at most NB = NN(C)2 branches where N(C)M is given by

$$N(C)M = \frac{N!}{(N-M)!\ M!} \qquad \text{Eq. A-1}$$

With N and M integers and L! is given by

$$L! = 1*2*3*....*(L-1)*L \qquad \text{Eq. A-2}$$

for any integer L. For any given open-channel flow system composed of nodes and branches, a precise system description results when a schematic network diagram of the system is produced. In this way the relationships between the node and branch components can be shown graphically prior to the data identification phase. Network components are either in existence, under developmentor proposed. For the purposes of the model, those components in existence and under development will be referred to as existing components to distinguish them from proposed components. These types of components differ with regard to the data associated with them as the data identification phase, which follows, will show.

2. Data Identification. Data used in the model can be either fixed or variable. If the data values associated with a component are known, they are an input to the model. On the other hand, if component data values are variable, they appear as a model output result.

a. Fixed Data Local Inflows. The local inflows into the network are taken to be fixed as Itj measured in volume units of water (such as acre-feet) during season t at node j. These volumes can be adjusted for any flow conditions of interest such as average annual or low flow. All local inflows such as flows into the network through rivers across the network boundary and from drainage areas vary as t ranges from 1 to NS where NS is the number of seasons. Figure A-1 shows a local inflow for NS = 2. The local inflows are taken to be constant over each season which is assumed to prevail at all network nodes. A closer approximation to the reality of flow varying over time results as NS increases.

b. Variable Data. Variable data can be either fixed which classifies it as fixed data or left variable. Thus this type of data is potentially variable or fixed.

(1) Variable Data for Nodes

(a) Operating Variables.

1. Rtj. Rtj represents the volume of water retained during season t at node j.

2. Dtj. Dtj represents the volume of water diverted from the network during season t at node j. Diversion may be made out of the network through rivers across the network boundary and into irrigation areas.

(b) Capacity Variable - Sj. Sj represents the water volume capacity of a proposed node with having either retention or diversion capability. Note that Sj does not vary from season to season but rather is constant over all seasons. No seasonal t notation is used with any capacity variables. Sj can be a bound on either Rtj or Rtj and Dtj in a node having retention and diversion capability. This must be specified on a node-by-node basis.

(2) Variable Data for Branches

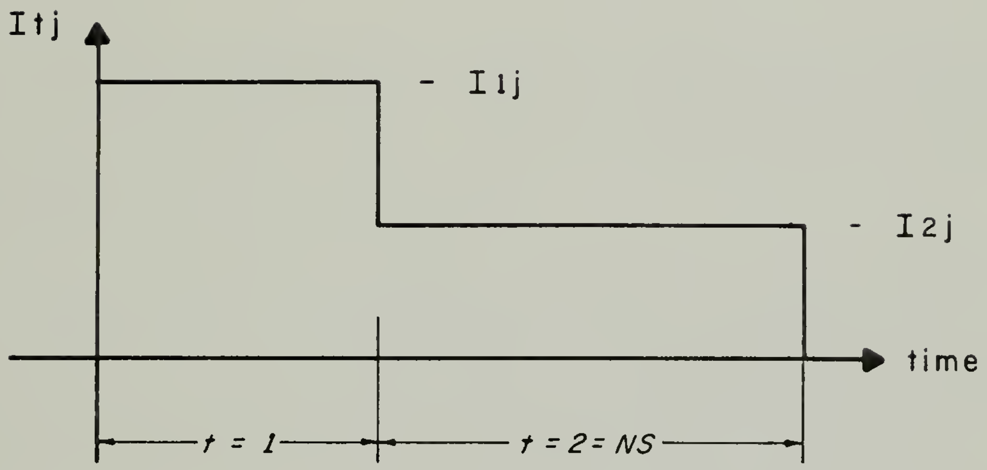
(a) Operating Variable - Qtjk. Qtjk represents the volume of water during season t which has flowed from node j to node k.

(b) Capacity Variable - Sjk. Sjk represents the water volume capacity of a proposed branch with flow from node j to node k. Sjk, like Sj mentioned previously, does not exhibit any seasonal dependence through the t notation.

c. Estimating the Number of Variables in a Problem. The number of variables in a given problem is a major determiner of computer execution time required for problem solution. With the

FIGURE A-1

TYPICAL LOCAL INFLOW DATA



information given to this point in the discussion, it is possible to obtain an upper limit on the number of variables, NV, for a network containing NN nodes and NB branches:

$$NV \leq 2*NS*NN+NN+NS*NB+NB \qquad \text{Eq. A-3}$$

In Eq. A-3 the assumption is made that the worst possible condition exists in that all nodes have retention and diversion capability (implies 2*NS operating variables per node) and are proposed (implies NN capacity variables). For the NB branches in Eq. A-3 the worst possible condition is that all branches having a total of NS*NB operating variables are proposed (implies NB capacity variables). Substitution from the previously discussed relation

$$NB \leq NN(C)2 \qquad \text{Eq. A-4}$$

gives an upper limit to NV independent of NB as

$$NV \leq NN* (2*NS+1) + (NN(C)2) * (NS+1) \qquad \text{Eq. A-5}$$

In practice, NV will be much less than either upper limit set in Eqs. A-4 or -5 because some nodes will neither have retention or diversion capability nor be proposed nodes. Moreover, most branches will not be proposed branches. An additional factor which lowers NV is that many variables will be fixed in practice.

3. Formulation of Objective Functions. Given a set of variables resulting from the data identification phase, objective functions can be established in terms of these variables. Ultimately, these functions are to be optimized (maximized or minimized depending upon the function in question) subject to constraint restrictions. Two independent objective functions, COBJ and BOBJ, are to be considered. BOBJ is the benefit objective function to be maximized, and COBJ is the cost objective function to be minimized. A third, but dependent, net benefit objective function to be maximized, NOBJ, is related to BOBJ and COBJ by

$$NOBJ = BOBJ - COBJ \qquad \text{Eq. A-6}$$

This definition of NOBJ requires that BOBJ and COBJ be measured in equivalent units such as monetary units (dollars) or volume units (acre-feet). Since NOBJ is related to the independent objective functions BOBJ and COBJ through Eq. A-6, it is only necessary to study BOBJ and COBJ in detail.

a. BOBJ. The benefit objective function in its most general form contains contributions from the nodes and the branches as

$$BOBJ = \sum_{\substack{j \\ \text{nodes}}} (\sum_{t=1}^{NS} (brvtj*Rtj = brftj + bdvtj * Dtj + bdftj) + bsvj*Sj + bsfj)$$

$$+ \sum_{\substack{kl \\ \text{branches}}} (\sum_{t=1}^{NS} (bqvtkl*Qtkl + bqftkl) + bsvkl*Skl + bsfkl) \qquad \text{Eq. A-7}$$

In Eq. A-7, the lower-case lettered coefficients and constants are defined as follows:

(1) brvtj. brvtj is the benefit coefficient (measured in benefit units per unit volume) for variable benefit attributable to Rtj.

(2) brftj. brftj is the benefit constant (measured in benefit units) for fixed benefit attributable to Rtj.

(3) bdvtj. bdvtj is the benefit coefficient (measured in benefit units per unit volume) for variable benefit attributable to Dtj.

(4) bdftj. bdftj is the benefit constant (measured in benefit units) for fixed benefit attributable to Dtj.

(5) bsvj. bsvj is the benefit coefficient (measured in benefit units per unit volume) for variable benefit attributable to Sj (present only if the node is proposed).

(6) bsfj. bsfj is the benefit constant (measured in benefit units) for fixed benefit attributable to Sj (present only if the node is proposed).

(7) bqvtkl. bqvtkl is the benefit coefficient (measured in benefit units per unit volume) for variable benefit attributable to Qtkl.

(8) bqftkl. bqftkl is the benefit constant (measured in benefit units) for fixed benefit attributable to Qtkl.

(9) bsvkl. bsvkl is the benefit coefficient measured in benefit units per unit volume) for variable benefit attributable to Skl (present only if the branch is proposed.)

(10) bsfkl. bsfkl is the benefit constant (measured in benefit units) for fixed benefit attributable to Skl (present only if the branch is proposed).

b. COBJ. The cost objective function in its most general form is quite similar to BOBJ except for the difference in naming the constants and coefficients associated with the network operating and capacity variables:

$$\text{COBJ} = \sum_{\substack{j \\ \text{nodes}}} \left(\sum_{t=1}^{NS} (\text{crvtj*Rtj} + \text{crftj} + \text{cdvtj * Dtj+cdftj}) + \text{csvj*Sj} + \text{csfj} \right)$$

$$+ \sum_{\substack{kl \\ \text{branches}}} \left(\sum_{t=1}^{NS} (\text{cqvtkl * Qtkl} + \text{cqftkl}) + \text{csvkl*Skl} + \text{csfkl} \right) \quad \text{Eq. A-8}$$

In Eq. A-8, the lower-case lettered coefficients and constants are defined as follows:

(1) crvtj. crvtj is the cost coefficient (measured in cost units per unit volume) for variable cost attributable to Rtj.

(2) crftj. crftj is the cost constant (measured in cost units) for fixed cost attributable to Rtj.

(3) cdvtj. cdvtj is the cost coefficient (measured in cost units per unit volume) for variable cost attributable to Dtj.

(4) cdftj. cdftj is the cost constant (measured in cost units) for fixed cost attributable to Dtj.

(5) csvj. csvj is the cost coefficient (measured in cost units per unit volume) for variable cost attributable to Sj (present only if the node is proposed).

(6) csfj. csfj is the cost constant (measured in cost units) for fixed cost attributable to Sj (present only if the node is proposed).

(7) cqvtkl. cqvtkl is the cost coefficient (measured in cost units.per unit volume) for variable cost attributable to Qtkl.

(8) cqftkl. cqftkl is the cost constant (measured in cost units) for fixed cost attributable to Qtkl.

(9) csvkl. csvkl is the cost coefficient measured in cost units per unit volume) for variable cost attributable to Skl (present only if the branch is proposed.)

(10) csfkl. csfkl is the cost constant (measured in cost units) for fixed cost attributable to Skl (present only if the branch is proposed).

c. A Note on Working with Objective Functions. BOBJ and COBJ as defined by Eqs. A-7 and A-8, respectively, introduce the requirement for a large number of coefficients and constants to be computed. Inspection of these objective function equations shows that, for each objective equation, one coefficient and one constant is introduced for each variable in the equation. Recollection of Eq. A-5 establishes an upper bound on NC, the number of coefficients and constants as

$$NC \leq 2{*}NV = 2{*}\ (NN{*}\ (2{*}NS+1)\ +(NN(C)2){*}(NS+1)) \qquad \text{Eq. A-9}$$

In practice, however, NC is much smaller than 2*NV because certain items of the variable data are vixed and certain other variable data items such as either retention or diversion capability at many nodes are non-existent. In addition, many coefficients and constants are assumed to be seasonally independent or to be zero in practical situations.

4. Constraint Restrictions. Among the operating and capacity variables associated with a network, constraint functions exist which limit the values of the objective functions by limiting the values the variables can assume in a given problem. The types of constraint restrictions considered in this model are those which express network flow continuity, component capacity limits, special constraints and variable bounds. It is possible to estimate the maximum number of constraints as the final portion of this discussion, Part A-4-e shows.

a. Continuity Equations. At each node j during each season t a continuity equation is required in the form

$$\sum_{\substack{k\\ \text{in}}} Qtkj - \sum_{\substack{l\\ \text{out}}} Qtjl - Dtj + Itj = Rtj - R\bar{t}j \qquad \text{Eq. A-10}$$

where

$$\bar{t} = \begin{cases} t-1, & t = 2, 3, \ldots . \ NS \\ NS, & t = 0 \end{cases} \qquad \text{Eq. A-11}$$

In Eq. A-10, the sum of the inflows and the outflows during season t at node j must equal the change in storage at that node. The convention is adopted that flow into a node is positive, and flow from a node is negative. The known local inflow Itj is positive. Since Itj is always known and Rtj and $R\bar{t}j$ usually are variable, they can be transposed in Eq. A-10, and the equation can be referred to as Ctj for linear programming purposes.

$$Ctj: \sum_{\substack{k \\ in}} Qtkj - \sum_{\substack{l \\ out}} Qtkl - Rtj + R\bar{t}j - Dtj = Itj \qquad \text{Eq. A-12}$$

This equation format is such that all variables appear on the left-hand side (LHS) and fixed values appear on the right-hand side (RHS). This format is used in all model equations. If any variables associated with node j assume a fixed, known value, they can be shifted to the RHS of Ctj in Eq. A-12. When t = 1, Eq. A-11 shows that $\bar{t}$ = NS which indicates that the seasons are taken to form a cyclic pattern with repetition every NS seasons. This assumption can, of course, be removed should it be desirable to simulate other conditions by letting $\bar{t}$ assume any given value when t = 0.

b. Capacity Upper Bounds. Upper bound relationships involve network component operating variables and, where present in proposed components, capacity variables. For a general node j during season t, the upper bound relationship is

$$Rtj + Dtj \leq Sj \qquad \text{Eq. A-13}$$

where it is assumed that the component j must have the capacity to retain the amount of water Dtj diverted from that component in season t. Likewise for a branch from node j to node k during season t, the upper bound relationship is

$$Qtjk \leq Sjk \qquad \text{Eq. A-14}$$

If the components of the network are existing, Sj and Sjk are fixed and appropriately appear on the RHS of Eqs. A-13 and A-14 respectively. However, if the components are proposed, Sj and Sjk are variables which require that they appear on the LHS of Eqs. A-13 and 14, respectively. In this case, the most general forms of Eqs. 13 and 14 appear referred to as Btj and Btjk, respectively, for linear programming purposes.

$$Btj: \ Rtj + Dtj - Sj \leq 0 \qquad \text{Eq. A-15}$$

$$Btjk: \ Qtjk - Sjk \leq 0 \qquad \text{Eq. A-16}$$

Any variable which is fixed at a known value can be transferred to the RHS of Eqs. A-15 and A-16. In the event that only one unknown variable remains on the LHS of Eq. A-15 or A-16, these relations degenerate to individual variable bounds which are discussed in Part A-4-d.

c. Special Constraints. Special constraints involve linear combinations of any of the variables referred to in the preceding discussion. These constraints arise from special conditions pertaining to the specific problem under discussion and have the general form

SP: (linear combination of variables)(≤, ≥ or =)(RHS) Eq. A-17

where one of the relations (≤, ≥ or =) is chosen to relate the linear combination of variables to the known RHS. An example of a case requiring constraints of the Sptj would be an area in which diversion water rights are stated for a group of diversion structures but not specified for each structure within the group.

d. Individual Variable Bounds. It is possible for each variable identified in the network to have upper and lower bounds in the form

(greatest lower bound) ≤ variable ≤ (least upper bound) Eq. A-18

Table A-1 shows sources of possible upper and lower bounds for the variables associated with the network.

Table A-1

Individual Variable Bounds

	Variable	Upper Bound Sources	Lower Bound Sources
Operating	Rtj	Sj (if proposed) Fixed facility size (if existing)	Recreation volume Flood control volume Required fish and wildlife volumes
Operating	Dtj	Sj (if proposed) Fixed facility size (if existing) Erosion	Municipal requirements and rights Irrigation requirements and rights
Operating	Qtjk	Sjk (if proposed) Fixed channel size (if existing) Erosion	Sedimentation Stagnation User requirements and rights
Capacity	Sj	Physical properties of facility region Facility materials	None (Capacity can be zero if optimization requires it)
Capacity	Sjk	Physical properties of branch region	None (Capacity can be zero if optimization requires it)

e. Estimating the Number of Constraints in a Problem. An additional major determiner of computer execution time is the number of constraints in a problem which are of the Ctj, Btj, Btjk, or SP type. For existing commercial linear programming software packages, such as CDC OPHELIE and IBM MPS, the number of constraints of the individual variable bound (Part A-4-d) type are treated separately and as such are not major determiners of computer execution time. In order to estimate an upper limit to NR, the number of constraints (as distinguished for the individual variable bounds just discussed), it is necessary to assume that all network components are proposed and that all nodes have retention and diversion capability. The result is

$$NR \leq NS*(2 * NN + NN(C)2) + NSP \qquad \text{Eq. A-19}$$

In Eq. A-19 NB is bounded by NN(C)2 through Eq. A-4, 2 * NN refers to the number of constraints of the Ctj and Btj types per season, NN(C)2 refers to the number of constraints of the Btjk type per season, NSP refers to the total number of constraints of the SP type in the model.

5. Application of the Mathematical Model. Once the four preceding phases of model development have been completed, it is possible to apply the model using available linear programming packaged programs such as CDC OPHELIE or IBM MPS. Both of these programs were used in model runs. Figure A-2 shows the typical appearance of the mathematical model as a set of mathematical relations. In estimating the computer execution time, NV, NR and the number of non-zero matrix elements can be computed and compared to results of computer manufacturers' benchmark tests for similar problems. The number of non-zero matrix elements results from evaluating for each equation of the types Ctj, Btj, Btjk, and SP the number of non-zero coefficients and summing the results.

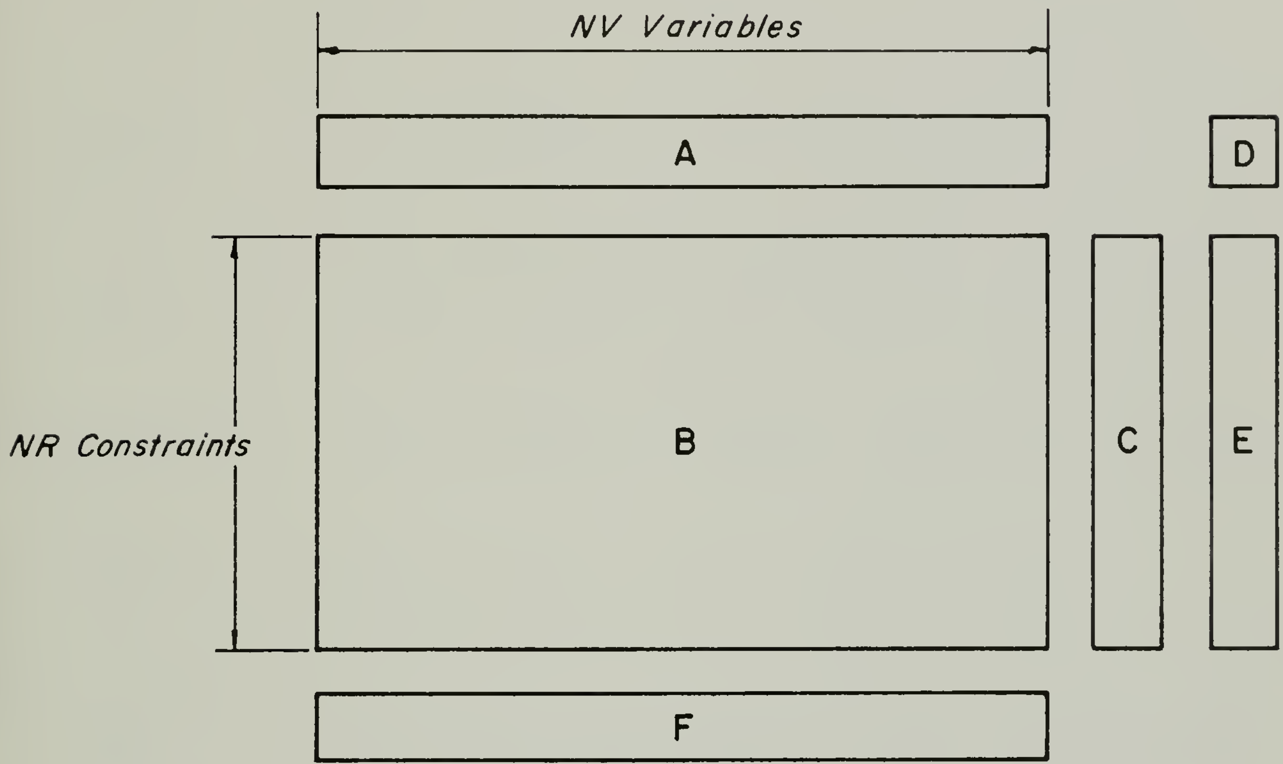
B. APPLYING THE MODEL TO AN EXAMPLE PROBLEM

1. System Description. Figure A-3 shows network schematic diagram symbols used for the purpose of executing an example of problem and the actual conservancy district problem which is discussed in Part IX of the report. An example network appears in Figure A-4. This network contains some of the components symbolized in Figure A-3. Local inflows Itj into the network are shown as crooked arrows on Figure A-4. The range of t over (1, 2) indicates that this is a two-season example.

2. Data Identification. The fixed data for local inflows in arbitrary volume units has been portrayed on Figure A-4. The variable data is shown in the columns of Table A-2.

FIGURE A-2

TYPICAL MATHEMATICAL MODEL APPEARANCE



A: Objective function coefficients

B: Constraint function coefficients (Ctj, Btj, Btjk and SP) – the NR x NV problem matrix

C: Relational column ($\leq$, $\geq$ or =)

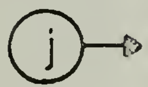
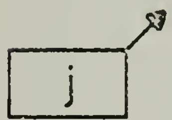
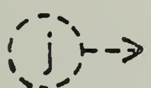
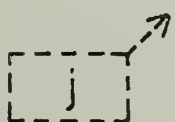
D: Negative summation of objective function constants

E: RHS column

F: Individual bound data, where appropriate, for each variable

FIGURE A-3

NETWORK SYMBOLS

Symbol	Description
j	Junction (no variables)
	Existing Reservoir (Rtj variable) *
	Existing Diversion (Dtj variable)
	Existing Reservoir - Diversion (Rtj and Dtj variable)
	Existing Natural Branch (Qtjk variable)
	Existing Man-made Branch or Canal (Qtjk variable)
	Proposed Reservoir (Rtj and Sj variable)
	Proposed Diversion (Dtj and Sj variable)
	Proposed Reservoir - Diversion (Rtj, Dtj and Sj variable)
	Proposed Branch or Canal (Qtjk and Sjk variable)

* *As the discussion in the text has indicated, any variable item cited in this table can be fixed in value by placing it on the RHS of equations containing it.*

FIGURE A—4

EXAMPLE NETWORK

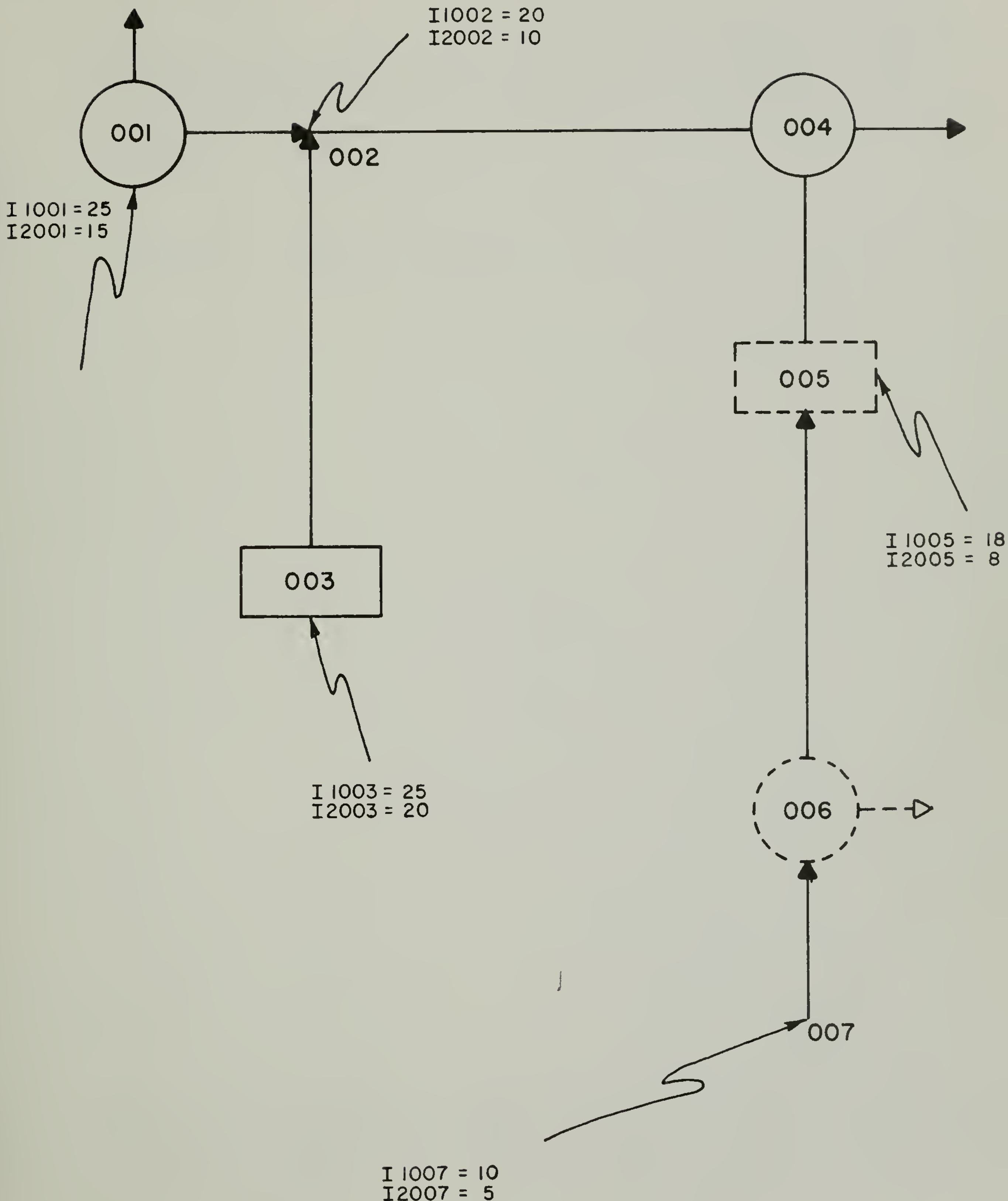


TABLE A-2
EXAMPLE DATA

VARIABLES

		D1001	D2001	R1003	R2003	D1004	D2004	R1005	R2005	S005	D1006	D2006	S006	Q1001002	Q2001002	Q1003002	Q2003002	Q1002004	Q2002004	Q1005004	Q2005004	Q1006005	Q2006005	Q1007006	Q2007006	RELATION	RHS
OBJECTIVE FUNCTIONS	BOBJ	1	2.5	20	10			23	10		3	4.5															
	COBJ									4			2														-1
	NOBJ	1	2.5	20	10			23	10	-4	3	4.5	-2														1
CONSTRAINTS	C 1001	-1												-1												=	-25
	C 2001		-1												-1											=	-15
	C 1002													1		1		-1								=	-20
	C 2002														1		1		-1							=	-10
	C 1003			-1	1											-1										=	-25
	C 2003			1	-1												-1									=	-20
	C 1004					-1												1		1						=	
	C 2004						-1												1		1					=	
	C 1005							-1	1											-1		1				=	-18
	C 2005							1	-1												-1		1			=	-8
	C 1006										-1											-1		1		=	
	C 2006											-1											-1		1	=	
	C 1007																							-1		=	-10
	C 2007																								-1	=	-5
	B 1005							1		-1																=	
	B 2005								1	-1																=	
	B 1006										1		-1													=	
	B 2006											1	-1													=	
BOUNDS	Upper	30	30	35	35					50			30														
	Lower			2	1			2	1					1	1	1	1	1	1	1	1	1	1	1	1		

This table is arranged in the format of Figure A-2 of Part A-5. Table A-2 will be referred to in the subsequent discussion covering the objective function and constraint restriction phases of the model development since it contains all of the information necessary to execute the example problem.

As an example of the column entries, node 001 is an existing diversion with operating variables D1001 and D2001 for seasons 1 and 2, respectively, to be determined by the optimization model. Node 005 is a proposed reservoir with operating variables R1005 and R2005 for seasons 1 and 2, respectively, and capacity variable S005 to be determined by the model. Branch 002004 is an existing natural branch with operating volumes between junction 002 and 004 represented by Q1002004 and Q2002004 for seasons 1 and 2, respectively. Inspection of the column entries in Figure 5 shows that there are NV=22 variables associated with this example.

3. <u>Formulation of Objective Functions.</u> With NV= 24 variables, it is possible to identify 24 coefficients and 24 constants for each objective function (BOBJ, COBJ or NOBJ). However, simplifying assumptions will be used based upon experience obtained in evaluating available benefit and cost data outlined in Part VIII. These assumptions apply to both this example network and the actual conservancy district network discussed in Part IX.

Benefits involved in a conservancy district are periodic fish and wildlife usage, recreation and crop and stock yields. It is assumed that these benefits are proportional to the node operating variable coefficients except in the cases of isolated special branches such as canals where benefits are assumed proportional to the flow volume operating variables. All benefit constants are taken to be zero since no benefits accrue when a component is not being operated or is nonexistent. The result of these benefit assumptions is that in Eq. A-7

$$brftj = bdftj = bsvj = bsfj = bqftkl = bsvkl = bsfkl = 0 \qquad \text{Eq. A-20}$$

$$bqftkl = 0 \qquad \text{Eq. A-21}$$

The BOBJ row of Table A-2 reflects these assumptions by assigning nonzero values to the usual nonzero benefit coefficients involved in the problem. As is true for the objective function segment (A of Figure A-2) the constraint segment (B of Figure A-2), the negative summation of objective function constants (D of Figure A-2) and the RHS (E of Figure A-2), no entry implies that the value of the entry is zero.

Costs considered for the conservancy district involve periodic amortization and interest (for proposed components only) and operation, maintenance and repair (for both proposed and existing components). Thus

the periodic amortization and interest attributed to existing components is taken as a fixed, sunk cost which is treated as a base from which costs are measured. The assumption is made that the remaining costs in the model can be attributed entirely to the capacity variables of proposed components except where pumping costs in a branch are involved. In this latter, infrequent case, the pumping costs are proportional to the flow volume operating variables Qtjk. The result of these assumptions is that in Eq. A-8

$$crvtj = crftj = cdvtj = cdftj = cqftkl = 0 \qquad \text{Eq. A-22}$$

Also, except in unusual cases such as branch pumping,

$$cqvtkl = cqftkl = 0 \qquad \text{Eq. A-23}$$

The effects of these assumptions appear in the COBJ row of Table A-2 where nonzero values are assigned to the usual nonzero cost coefficients involved in the problem. The total fixed constant cost which would appear with a negative value in the RHS column of the COBJ row, has been arbitrarily given a unit value. Notice that, consistent with the definition of NOBJ in Eq.A-6, the coefficients appearing in the NOBJ row of Table A - 2 are the differences between column coefficient entries of the BOBJ row and those of the COBJ row.

4. Constraint Restrictions. The constraint segment of Table A-2, which is similar to B of Figure A-2, contains NR=18 constraint relations of the Ctj and Btj type. Since there are no proposed branches in this example, no constraint relations of the Btjk type appear. Also no special constraints of the SP type are considered. A typical constraint equation, or matrix row, of the example is C2005, the continuity equation during season 2 at node 005 which is a proposed reservoir.

$$C2005: \; R1005 - R2005 - Q2005004 + Q2006005 = -8 \qquad \text{Eq. A-24}$$

The bounds segment of Table A-2 which resembles F of Figure A-2, summarizes the individual variable bounds of the type referred to in Part A-4-d. Unless a value is specified by an entry into this segment for upper bounds, those bounds are assumed to be infinity. No entry into this segment for lower bounds implies a lower bound of zero. In the example data of Table 2, for example, R1003 satisfies the relation

$$0 \leq R1003 \leq 35 \qquad \text{Eq. A-25}$$

while Q2001002 satisfies (by implication from blank entries) the relation

$$0 \leq Q2001002 \leq \infty \qquad \text{Eq. A-26}$$

5. Model Input Data. The linear programming software used for the development of this model was the CDC OPHELIE program. The example problem has also been executed using IBM MPS as Parts B-6 and 7 discuss.

Both the OPHELIE and MPS programs accept the same input data deck in MPS format. Each program will accept a description of the Matrix, RHS and bounds in this format. Figure A-5 shows the data from Table A-2 converted to MPS format. This data, containing only those entries from Figure A-2 which are not blank, is prepared on cards as follows:

a. NAME Card

(1) Columns 1-4 (NAME)

(2) Columns 15-22

Name of the problem using 1-8 alphanumeric characters, the first of which is alphabetic (HYDRO5, in this case)

b. ROWS Header Card. Columns 1-4 (ROWS)

c. ROWS Cards. These cards correspond to the names of the matrix rows shown in Table A-2.

(1) Column 2. Relation from Table A-2

(a) N
Free, such as the objective function rows.

(b) L
Less-than-or-equal ($\leq$) constraint

(c) G
Greater-than-or-equal ($\geq$) constraint (not used in Table A-2 but could occur in SP constraints)

(d) E
Equality (=) constraint

(2) Columns 5-12. Name of row using 1-8 alphanumeric characters, the first of which is alphabetic.

d. COLUMNS Header Card. Columns 1-7 (COLUMNS).

e. COLUMNS Cards. These cards introduce the non-zero matrix entries by referring to their column and row location and their values.

FIGURE A-5

MODEL INPUT DATA IN MPS FORMAT

```
NAME          HYDROS
ROWS
 N  BOBJ
 N  COBJ
 N  NOBJ
 E  C1001
 E  C2001
 E  C1002
 E  C2002
 E  C1003
 E  C2003
 E  C1004
 E  C2004
 E  C1005
 E  C2005
 E  C1006
 E  C2006
 E  C1007
 E  C2007
 L  B1005
 L  B2005
 L  B1006
 L  B2006
COLUMNS
    Q1001     BOBJ         1.0
    Q1001     NOBJ         1.0
    Q1001     C1001       -1.0
    Q2001     BOBJ         2.5
    Q2001     NOBJ         2.5
    Q2001     C2001       -1.0
    R1003     BOBJ         20.0
    R1003     NOBJ         20.0
    R1003     C1003       -1.0
    R1003     C2003        1.0
    R2003     BOBJ         10.0
    R2003     NOBJ         10.0
    R2003     C1003        1.0
    R2003     C2003       -1.0
    Q1004     C1004        -1.0
    Q2004     C2004        -1.0
    R1005     BOBJ         23.0
    R1005     NOBJ         23.0
    R1005     C1005       -1.0
    R1005     C2005        1.0
    R1005     B1005        1.0
    R2005     BOBJ         10.0
    R2005     NOBJ         10.0
    R2005     C1005        1.0
    R2005     C2005       -1.0
    R2005     B2005        1.0
    S005      COBJ           4.0
    S005      NOBJ          -4.0
    S005      B1005       -1.0
    S005      B2005       -1.0
    Q1006     BOBJ         3.0
    Q1006     NOBJ         3.0
    Q1006     C1006       -1.0
    Q1006     B1006        1.0
    Q2006     BOBJ         4.5
    Q2006     NOBJ         4.5
    Q2006     C2006       -1.0
    Q2006     B2006        1.0
    S006      COBJ          2.0
    S006      NOBJ         -2.0
    S006      B1006       -1.0
    S006      B2006       -1.0
    Q1001002  C1001       -1.0
    Q1001002  C1002        1.0
    Q2001002  C2001       -1.0
    Q2001002  C2002        1.0
    Q1002004  C1002       -1.0
    Q1002004  C1004        1.0
    Q2002004  C2002       -1.0
    Q2002004  C2004        1.0
    Q1003002  C1002        1.0
    Q1003002  C1003       -1.0
    Q2003002  C2002        1.0
    Q2003002  C2003       -1.0
    Q1005004  C1004        1.0
    Q1005004  C1005       -1.0
    Q2005004  C2004        1.0
    Q2005004  C2005       -1.0
    Q1006005  C1005        1.0
    Q1006005  C1006       -1.0
    Q2006005  C2005        1.0
    Q2006005  C2006       -1.0
    Q1007006  C1006        1.0
    Q1007006  C1007       -1.0
    Q2007006  C2006        1.0
    Q2007006  C2007       -1.0
RHS
    RUN4      COBJ        -1.0
    RUN4      NOBJ         1.0
    RUN4      C1001       -25.0
    RUN4      C2001       -15.0
    RUN4      C1002       -20.0
    RUN4      C2002       -10.0
    RUN4      C1003       -25.0
    RUN4      C2003       -20.0
    RUN4      C1005       -18.0
    RUN4      C2005       -8.0
    RUN4      C1007       -10.0
    RUN4      C2007       -5.0
BOUNDS
 UP B04       Q1001        30.0
 UP B04       Q2001        30.0
 UP B04       S005         50.0
 UP B04       S006         30.0
 UP B04       R1003        35.0
 LO B04       R1003        2.0
 UP B04       R2003        35.0
 LO B04       R2003        1.0
 LO B04       R1005        2.0
 LO B04       R2005        1.0
 LO B04       Q1001002       1.0
 LO B04       Q2001002       1.0
 LO B04       Q1002004       1.0
 LO B04       Q2002004       1.0
 LO B04       Q1003002       1.0
 LO B04       Q2003002       1.0
 LO B04       Q1005004       1.0
 LO B04       Q2005004       1.0
 LO B04       Q1006005       1.0
 LO B04       Q2006005       1.0
 LO B04       Q1007006       1.0
 LO B04       Q2007006       1.0
ENDATA
```

(1) Columns 5-12. Name of variable using 1-8 alphanumeric characters, the first of which is alphabetic.

(2) Columns 15-22. Name of row containing the matrix entry (one of the rows identified in the ROWS cards).

(3) Columns 25-36. Value of the matrix entry (free-form numeric format).

f. RHS Header Card. Columns 1-3 (RHS). This card introduces one or more RHS vectors.

g. RHS Cards

(1) Columns 5-12. Name of RHS vector using 1-8 alphanumeric characters, the first of which is alphabetic (RUN4, in this case).

(2) Columns 15-22. Name of row containing RHS entry (one of the rows identified in the ROWS cards) RHS values can be from either segment D or E of Figure A-2; that is, the negative of the fixed value of an objective function or the RHS of a matrix row.

(3) Columns 25-36. Value of the RHS entry (free form numeric format).

h. BOUNDS Header Card. Columns 1-6 (BOUNDS)

i. BOUNDS Cards. These cards introduce one or more bound sets to be used in the problem solutions.

(1) Columns 2-3. Bound type.

(a) UP. Upper bound-shown in Table A-2.

(b) LO. Lower bound-shown in Table A-2.

(c) FX. Fixed-value variable-not shown in TableA-2. This option is an artificial way to assign a known value to a variable without carrying it over to the RHS of objective or constraint rows as discussed in Part A-4.

(2) Columns 5-12. Name of BOUNDS set using 1-8 alphanumeric characters, the first of which is alphabetic (BD4, in this case).

(3) Columns 15-22. Name of bounded variable (one of the columns identified in the COLUMNS cards).

(4) Columns 25-36. Value of the bound (free-form numeric format).

j. ENDATA Card. Physically the last card in the MPS data deck to signal the end of the input data.

6. Model Program Statements

a. Model Flowchart. Figure A-6 shows the flowchart which applies to the optimization model developed for the example HYDRO5 as well as the conservancy district network. After the start at cirle 1 the MPS formatted input data is read from cards in box 2-7. In box 8, the problem is set up by selecting the appropriate matrix, RHS and BOUNDS set. The initial solution is obtained when BOBJ is maximized in box 9. Following the initial solution, COBJ is minimized and NOBJ is maximized, based upon the BOBJ solution as a starting point, in boxes 11 and 13, respectively, prior to the program finish at circle 15. The paper copy output data for the maximum BOBJ, minimum COBJ and maximum NOBJ solutions appears in box 10, 12, 14. Actual CDC OPHELIE and IBM MPS program statements to implement the model flowchart of Figure A-6 are discussed in Parts B-6-b and c, respectively.

b. CDC OPHELIE Program. Control program statements for the OPHELIE linear programming software package appear in Figure A-7. The applicable segments of the flowchart in Figure A-6 are keyed to the individual program statements in Figure A-7.

c. IBM MPS Program. Control program statements for the MPS linear programming software package appear in Figure A-8. The applicable segments of the flowchart in Figure A-6 are keyed to the individual program statements in Figure A-8.

7. Model Output Data

a. Items of Interest. The computer output listings from OPHELIE in Figure A-9 and from MPS in Figure A-10 contain large amounts of data. Only a portion of this data is of immediate interest to the water resources planner. In the following discussion, these items of interest are summarized. The key description symbols in brackets ([ ]) refer to annotations on Figures A-9 and 10.

(1) Maximum BOBJ Solution

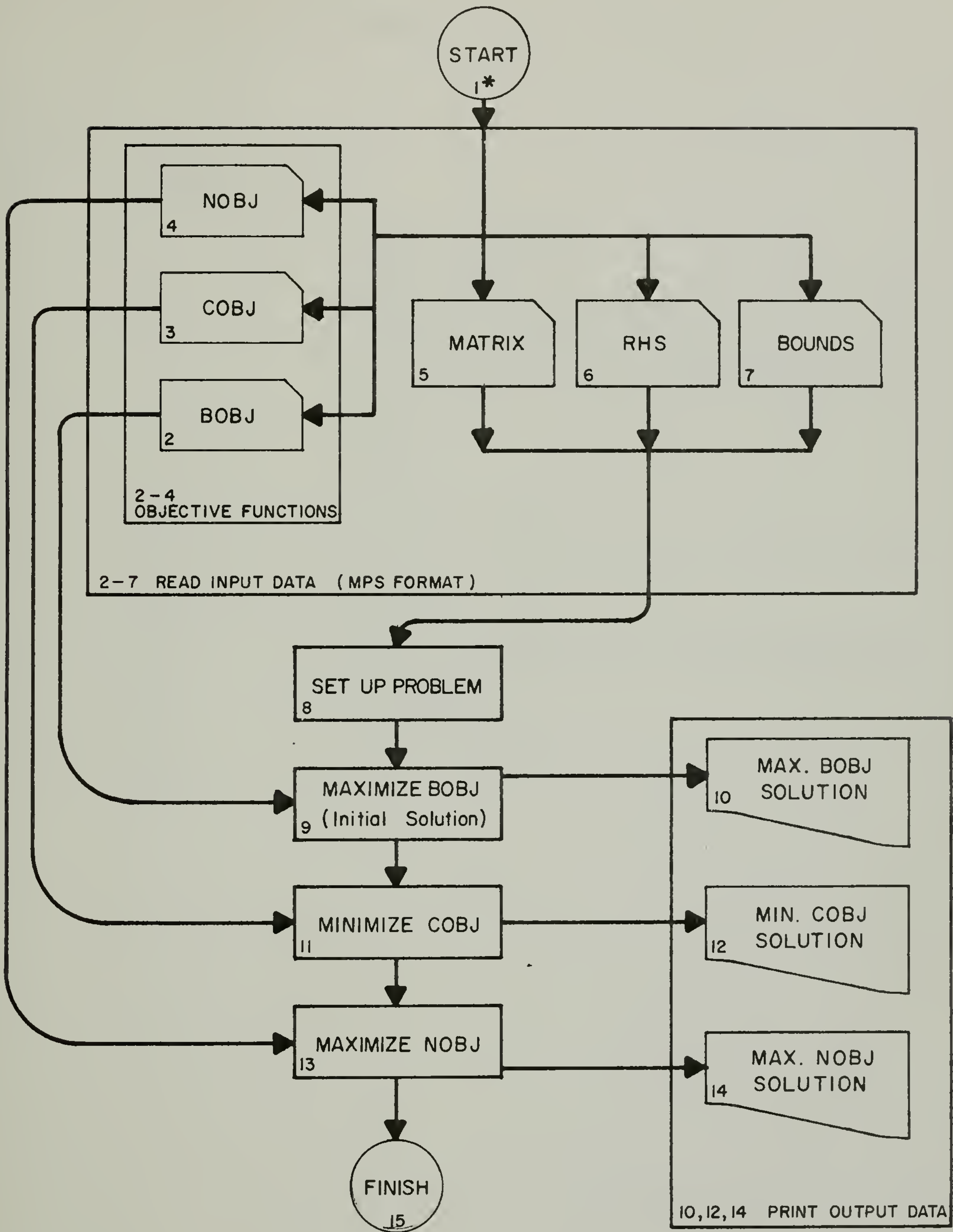
(a) Objective Function Name and Value [BB]

(b) Negative of other Objective Function Values. [BC], [BN]

(c) Variable Name List Column [BL]

FIGURE A-6

MODEL FLOWCHART



* NUMBERS REFER TO FLOWCHART SEGMENTS IN THE TEXT DISCUSSION AND IN FIGURES A-7 AND A-8

FIGURE A-7

CDC OPHELIE CONTROL PROGRAM

Figure A-6 Flowchart Segment Nos.	Card Number	Col. 2	Col. 6
(1)	1.	/M/	SUBROUTINE MAIN
(1)	2.		COMMON/CR/
(2-7)	3.		INTRODUCTION MPS(≠PROBLEM FILE=HYDRO5≠, ≠NOLIST≠, ≠LFT=GMTF4≠)
(8)	4.		CONVERSION(≠BND=BD4≠, ≠NOLIST≠)
(2, 9)	5.		SELECTION(≠OBJECTIVE=BOBJ≠, ≠RHS=RUN4≠)
(9)	6.		MAXIMIZE
(9)	7.		CRASH3
(9)	8.		CRASH2
(9)	9.		OPTIMIZE
(10)	10.		OUTPUT(≠LOGIC≠)
(3, 11)	11.		SELECTION(≠OBJECTIVE=COBJ≠, ≠RHS=RUN4≠)
(11)	12.		MINIMIZE
(11)	13.		OPTIMIZE
(12)	14.		OUTPUT(≠LOGIC≠)
(4, 13)	15.		SELECTION(≠OBJECTIVE=NOBJ≠, ≠RHS=RUN4≠)
(13)	16.		MAXIMIZE
(13)	17.		OPTIMIZE
(14)	18.		OUTPUT(≠LOGIC≠)
(15)	19.		EXIT
(15)	20.		END

FIGURE A-8

IBM MPS CONTROL PROGRAM

Figure A-6 Flowchart Segment Nos.	Card No.	Col. 10
(1)	1.	PROGRAM
(1)	2.	INITIALZ
(2-7)	3.	MOVE(XDATA, 'HYDRO5')
(2-7)	4.	MOVE(XPBNAME, 'PBFILE')
(8)	5.	CONVERT('SUMMARY')
(8)	6.	BCDOUT
(9)	7.	SETUP('BOUND', 'BD4', 'MAX')
(2, 9)	8.	MOVE(XOBJ, 'BOBJ')
(9)	9.	MOVE(XRHS, 'RUN4')
(9)	10.	PRIMAL
(10)	11.	SOLUTION
(11)	12.	SETUP('BOUND', 'BD4', 'MIN')
(3, 11)	13.	MOVE(XOBJ, 'COBJ')
(11)	14.	PRIMAL
(12)	15.	SOLUTION
(13)	16.	SETUP('BOUND', 'BD4', 'MAX')
(4, 13)	17.	MOVE(XOBJ, 'NOBJ')
(13)	18.	PRIMAL
(14)	19.	SOLUTION
(15)	20.	EXIT
(15)	21.	END

FIGURE A-9a

OPHELIE MAXIMUM BOBJ SOLUTION

HYOROS

SOLUTION TYPE = PHASE 2 - OPTINUM

NUMBER OF BASIS CHANGES
SINCE THE START OF THE PROBLEM = 27
NAME OF THE OBJECTIVE FUNCTION = ≠BOBJ≠
NAME OF SELECTEO ISET = ≠≠
NAME OF SELECTEO RHS = ≠RUN4≠ [BB]
NAME OF SELECTEO RANGES SET = ≠≠
NAME OF SELECTEO BOUNOS SET = ≠BO4≠
VALUE OF THE OBJECTIVE FUNCTION = 2804.00000

LOGICAL ANO STRUCTURAL VARIABLES

TYPE	VARIABLE NAME	STAT	VALUE	CONSTRAINT VALUE	CONSTRAINT LOWER BOUNO	CONSTRAINT UPPER BOUNO	DUAL VALUE	COMMENTS
F	BOBJ	B	-2804.00000	2804.00000	NONE	NONE	-1.00000	
F	COBJ	B	-219.00000	218.00000	NONE	NONE	0.00000	
F	NOBJ	B	-2585.00000	2586.00000	NONE	NONE	0.00000	
Z	C1001	NF	[BC] 0.00000	-25.00000	-25.00000	-25.00000	-1.00000	
Z	C2001	NF	0.00000	-15.00000	-15.00000	-15.00000	-2.50000	
Z	C1002	NF	[BN] 0.00000	-20.00000	-20.00000	-20.00000	0.00000	
Z	C2002	NF	0.00000	-10.00000	-10.00000	-10.00000	0.00000	
Z	C1003	NF	0.00000	-25.00000	-25.00000	-25.00000	0.00000	
Z	C2003	NF	0.00000	-20.00000	-20.00000	-20.00000	0.00000	
Z	C1004	NF	0.00000	0.00000	0.00000	0.00000	0.00000	
Z	C2004	NF	0.00000	0.00000	0.00000	0.00000	0.00000	
Z	C1005	NF	0.00000	-18.00000	-18.00000	-18.00000	0.00000	
Z	C2005	NF	0.00000	-8.00000	-8.00000	-8.00000	0.00000	
Z	C1006	NF	0.00000	0.00000	0.00000	0.00000	-3.00000	
Z	C2006	NF	0.00000	0.00000	0.00000	0.00000	-4.50000	
Z	C1007	NF	0.00000	-10.00000	-10.00000	-10.00000	-3.00000	

HYOROS ≠BOBJ≠ ≠≠ ≠RUN4≠

TYPE	VARIABLE NAME	STAT	VALUE	CONSTRAINT VALUE	CONSTRAINT LOWER BOUNO	CONSTRAINT UPPER BOUNO	DUAL VALUE	COMMENTS
Z	C2007	NF	0.00000	-5.00000	-5.00000	-5.00000	-4.50000	
P	B1005	NF	0.00000	0.00000		0.00000	23.00000	
P	B2005	NF	0.00000	0.00000		0.00000	10.00000	
P	B1006	NF	0.00000	0.00000		0.00000	0.00000	
P	B2006	BF	5.00000	-5.00000		0.00000	0.00000	

HYOROS ≠BOBJ≠ ≠≠ ≠RUN4≠

TYPE	[BL] VARIABLE NAME	STAT	[BV] VALUE	COST	LOWER BOUND	UPPER BOUNO	OJ	COMMENTS
B	O1001	BF	24.00000	1.00000	0.00000	30.00000	0.00000	
B	O2001	BF	14.00000	2.50000	0.00000	30.00000	0.00000	
B	R1003	UP	35.00000	20.00000	2.00000	35.00000	-20.00000	
B	R2003	UP	35.00000	10.00000	1.00000	35.00000	-10.00000	
P	O1004	BF	65.00000	0.00000	0.00000	NONE	0.00000	
P	O2004	BF	40.00000	0.00000	0.00000	NONE	0.00000	
P	R1005	BF	50.00000	23.00000	2.00000	NONE	0.00000	
P	R2005	BF	50.00000	10.00000	1.00000	NONE	0.00000	
B	S005	UP	50.00000	0.00000	0.00000	50.00000	-33.00000	
P	O1006	BF	9.00000	3.00000	0.00000	NONE	0.00000	
P	O2006	BF	4.00000	4.50000	0.00000	NONE	0.00000	
B	S006	BF	9.00000	0.00000	0.00000	30.00000	0.00000	
P	Q1001002	NF	1.00000	0.00000	1.00000	NONE	1.00000	
P	Q2001002	NF	1.00000	0.00000	1.00000	NONE	2.50000	
P	Q1002004	BF	46.00000	0.00000	1.00000	NONE	0.00000	
P	Q2002004	BF	31.00000	0.00000	1.00000	NONE	0.00000	
P	Q1003002	BF	25.00000	0.00000	1.00000	NONE	0.00000	
P	Q2003002	BF	20.00000	0.00000	1.00000	NONE	0.00000	
P	Q1005004	BF	19.00000	0.00000	1.00000	NONE	0.00000	
P	Q2005004	BF	9.00000	0.00000	1.00000	NONE	0.00000	
P	Q1006005	NF	1.00000	0.00000	1.00000	NONE	3.00000	
P	Q2006005	NF	1.00000	0.00000	1.00000	NONE	4.50000	
P	Q1007006	BF	10.00000	0.00000	1.00000	NONE	0.00000	
P	Q2007006	BF	5.00000	0.00000	1.00000	NONE	0.00000	

FIGURE A-9b

OPHELIE MINIMUM COBJ SOLUTION

HYDROS

SOLUTION TYPE = PHASE 2 - OPTIMUM

NUMBER OF BASIS CHANGES
 SINCE THE START OF THE PROBLEM = 31
NAME OF THE OBJECTIVE FUNCTION = ≠COBJ≠
NAME OF SELECTED ISET = ≠≠
NAME OF SELECTED RHS = ≠RUN4≠
NAME OF SELECTED RANGES SET = ≠≠
NAME OF SELECTED BOUNDS SET = ≠B04≠
VALUE OF THE OBJECTIVE FUNCTION = 9.00000

CC

LOGICAL AND STRUCTURAL VARIABLES

CB CN

TYPE	VARIABLE NAME	STAT	VALUE	CONSTRAINT VALUE	CONSTRAINT LOWER BOUND	CONSTRAINT UPPER BOUND	DUAL VALUE	COMMENTS
F	BOBJ	B	-1175.00000	1175.00000	NONE	NONE	0.00000	
F	COBJ	B	-9.00000	8.00000	NONE	NONE	1.00000	
F	NOBJ	B	-1166.00000	1167.00000	NONE	NONE	0.00000	
Z	C1001	NF	0.00000	-25.00000	-25.00000	-25.00000	0.00000	
Z	C2001	NF	0.00000	-15.00000	-15.00000	-15.00000	0.00000	
Z	C1002	NF	0.00000	-20.00000	-20.00000	-20.00000	0.00000	
Z	C2002	NF	0.00000	-10.00000	-10.00000	-10.00000	0.00000	
Z	C1003	NF	0.00000	-25.00000	-25.00000	-25.00000	0.00000	
Z	C2003	NF	0.00000	-20.00000	-20.00000	-20.00000	0.00000	
Z	C1004	NF	0.00000	0.00000	0.00000	0.00000	0.00000	
Z	C2004	NF	0.00000	0.00000	0.00000	0.00000	0.00000	
Z	C1005	NF	0.00000	-18.00000	-18.00000	-18.00000	0.00000	
Z	C2005	NF	0.00000	-8.00000	-8.00000	-8.00000	0.00000	
Z	C1006	NF	0.00000	0.00000	0.00000	0.00000	0.00000	
Z	C2006	NF	0.00000	0.00000	0.00000	0.00000	.00000	
Z	C1007	NF	0.00000	-10.00000	-10.00000	-10.00000	0.00000	

HYDROS ≠COBJ≠ ≠≠ ≠RUN4≠

TYPE	VARIABLE NAME	STAT	VALUE	CONSTRAINT VALUE	CONSTRAINT LOWER BOUND	CONSTRAINT UPPER BOUND	DUAL VALUE	COMMENTS
Z	C2007	NF	0.00000	-5.00000	-5.00000	-5.00000	.00000	
P	B1005	NF	0.00000	0.00000		0.00000	4.00000	
P	B2005	NF	0.00000	0.00000		0.00000	0.00000	
P	B1006	NF	0.00000	0.00000		0.00000	0.00000	
P	B2006	NF	0.00000	0.00000		0.00000	2.00000	

HYDROS ≠COBJ≠ ≠≠ ≠RUN4≠

TYPE	VARIABLE NAME (CL)	STAT	VALUE (CV)	COST	LOWER BOUND	UPPER BOUND	DJ	COMMENTS
B	D1001	BF	24.00000	0.00000	0.00000	30.00000	0.00000	
B	D2001	BF	14.00000	0.00000	0.00000	30.00000	0.00000	
B	R1003	UP	35.00000	0.00000	2.00000	35.00000	0.00000	
B	R2003	UP	35.00000	0.00000	1.00000	35.00000	0.00000	
P	D1004	BF	74.00000	0.00000	0.00000	NONE	0.00000	
P	D2004	BF	44.00000	0.00000	0.00000	NONE	0.00000	
P	R1005	NF	2.00000	0.00000	2.00000	NONE	4.00000	
P	R2005	BF	2.00000	0.00000	1.00000	NONE	0.00000	
B	S005	BF	2.00000	4.00000	0.00000	50.00000	0.00000	
P	D1006	BF	0.00000	0.00000	0.00000	NONE	0.00000	
P	D2006	NF	0.00000	0.00000	0.00000	NONE	2.00000	
B	S006	BF	0.00000	2.00000	0.00000	30.00000	0.00000	
P	D1001002	NF	1.00000	0.00000	1.00000	NONE	0.00000	
P	D2001002	NF	1.00000	0.00000	1.00000	NONE	0.00000	
P	Q1002004	BF	46.00000	0.00000	1.00000	NONE	0.00000	
P	Q2002004	BF	31.00000	0.00000	1.00000	NONE	0.00000	
P	Q1003002	BF	25.00000	0.00000	1.00000	NONE	0.00000	
P	Q2003002	BF	20.00000	0.00000	1.00000	NONE	0.00000	
P	Q1005004	BF	28.00000	0.00000	1.00000	NONE	0.00000	
P	Q2005004	BF	13.00000	0.00000	1.00000	NONE	0.00000	
P	Q1006005	BF	10.00000	0.00000	1.00000	NONE	0.00000	
P	Q2006005	BF	5.00000	0.00000	1.00000	NONE	0.00000	
P	Q1007006	BF	10.00000	0.00000	1.00000	NONE	0.00000	
P	Q2007006	BF	5.00000	0.00000	1.00000	NONE	0.00000	

FIGURE A - 9c

OPHELIE MAXIMUM NOBJ SOLUTION

HYOROS

SOLUTION TYPE = PHASE 2 - OPTIMUM

NUMBER OF BASIS CHANGES
SINCE THE START OF THE PROBLEM = 35
NAME OF THE OBJECTIVE FUNCTION = ≠NOBJ≠
NAME OF SELECTED ISET = ≠≠
NAME OF SELECTED RHS = ≠RUN4≠ [NN]
NAME OF SELECTED RANGES SET = ≠≠
NAME OF SELECTED BOUNDS SET = ≠BD4≠
VALUE OF THE OBJECTIVE FUNCTION = 2585.00000

LOGICAL AND STRUCTURAL VARIABLES

TYPE	VARIABLE NAME	STAT	VALUE	CONSTRAINT VALUE	CONSTRAINT LOWER BOUND	CONSTRAINT UPPER BOUND	DUAL VALUE	COMMENTS
F	BOBJ	B	2804.00000	2804.00000	NONE	NONE	0.00000	
F	COBJ	B	219.00000	218.00000	NONE	NONE	0.00000	
F	NOBJ	B	2585.00000	2586.00000	NONE	NONE	-1.00000	
Z	C1001	NF	0.00000	-25.00000	-25.00000	-25.00000	-1.00000	
Z	C2001	NF	0.00000	-15.00000	-15.00000	-15.00000	-2.50000	
Z	C1002	NF	0.00000	-20.00000	-20.00000	-20.00000	0.00000	
Z	C2002	NF	0.00000	-10.00000	-10.00000	-10.00000	0.00000	
Z	C1003	NF	0.00000	-25.00000	-25.00000	-25.00000	0.00000	
Z	C2003	NF	0.00000	-20.00000	-20.00000	-20.00000	0.00000	
Z	C1004	NF	0.00000	0.00000	0.00000	0.00000	0.00000	
Z	C2004	NF	0.00000	0.00000	0.00000	0.00000	0.00000	
Z	C1005	NF	0.00000	-18.00000	-18.00000	-18.00000	0.00000	
Z	C2005	NF	0.00000	-8.00000	-8.00000	-8.00000	0.00000	
Z	C1006	NF	0.00000	0.00000	0.00000	0.00000	-1.00000	
Z	C2006	NF	0.00000	0.00000	0.00000	0.00000	-4.50000	
Z	C1007	NF	0.00000	-10.00000	-10.00000	-10.00000	-1.00000	

[NB] [NC]

HYOROS ≠NOBJ≠ ≠≠ ≠RUN4≠

TYPE	VARIABLE NAME	STAT	VALUE	CONSTRAINT VALUE	CONSTRAINT LOWER BOUND	CONSTRAINT UPPER BOUND	DUAL VALUE	COMMENTS
Z	C2007	NF	0.00000	-5.00000	-5.00000	-5.00000	-4.50000	
P	B1005	NF	0.00000	0.00000		0.00000	23.00000	
P	B2005	NF	0.00000	0.00000		0.00000	10.00000	
P	B1006	NF	0.00000	0.00000		0.00000	2.00000	
P	B2006	BF	5.00000	-5.00000		0.00000	0.00000	

HYOROS ≠NOBJ≠ ≠≠ ≠RUN4≠

TYPE	[NL] VARIABLE NAME	STAT	[NV] VALUE	COST	LOWER BOUND	UPPER BOUND	DJ	COMMENTS
B	D1001	BF	24.00000	1.00000	0.00000	30.00000	0.00000	
B	D2001	BF	14.00000	2.50000	0.00000	30.00000	0.00000	
B	R1003	UP	35.00000	20.00000	2.00000	35.00000	-20.00000	
B	R2003	UP	35.00000	10.00000	1.00000	35.00000	-10.00000	
P	D1004	BF	65.00000	0.00000	0.00000	NONE	0.00000	
P	D2004	BF	40.00000	0.00000	0.00000	NONE	0.00000	
P	R1005	BF	50.00000	23.00000	2.00000	NONE	0.00000	
P	R2005	BF	50.00000	10.00000	1.00000	NONE	0.00000	
B	S005	UP	50.00000	-4.00000	0.00000	50.00000	-29.00000	
P	D1006	BF	9.00000	3.00000	0.00000	NONE	0.00000	
P	D2006	BF	4.00000	4.50000	0.00000	NONE	0.00000	
B	S006	BF	9.00000	-2.00000	0.00000	30.00000	0.00000	
P	Q1001002	NF	1.00000	0.00000	1.00000	NONE	1.00000	
P	Q2001002	NF	1.00000	0.00000	1.00000	NONE	2.50000	
P	Q1002004	BF	46.00000	0.00000	1.00000	NONE	0.00000	
P	Q2002004	BF	31.00000	0.00000	1.00000	NONE	0.00000	
P	Q1003002	BF	25.00000	0.00000	1.00000	NONE	0.00000	
P	Q2003002	BF	20.00000	0.00000	1.00000	NONE	0.00000	
P	Q1005004	BF	19.00000	0.00000	1.00000	NONE	0.00000	
P	Q2005004	BF	9.00000	0.00000	1.00000	NONE	0.00000	
P	Q1006005	NF	1.00000	0.00000	1.00000	NONE	1.00000	
P	Q2006005	NF	1.00000	0.00000	1.00000	NONE	4.50000	
P	Q1007006	BF	10.00000	0.00000	1.00000	NONE	0.00000	
P	Q2007006	BF	5.00000	0.00000	1.00000	NONE	0.00000	

FIGURE A-10a

MPS MAXIMUM BOBJ SOLUTION

EXECUTOR. MPS/360 V2-M8

SOLUTION %OPTIMAL□

TIME # 0.44 MINS. ITERATION NUMBER # 20

...NAME...	...ACTIVITY...		DEFINED AS
FUNCTIONAL	2804.00000	BB	BOBJ
RESTRAINTS			RUN4
BOUNDS....			BD4

EXECUTOR. MPS/360 V2-M8

SECTION 1 - ROWS

	NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT.	..UPPER LIMIT.	.DUAL ACTIVITY
	1	BOBJ	BS	2804.00000	2804.00000-	NONE	NONE	1.00000
	2	COBJ	BS	260.00000	261.00000- BC	NONE	NONE	.
	3	NOBJ	BS	2544.00000	2543.00000- BN	NONE	NONE	.
	4	C1001	EQ	25.00000-	.	25.00000-	25.00000-	1.00000
	5	C2001	EQ	15.00000-	.	15.00000-	15.00000-	2.50000
A	6	C1002	EQ	20.00000-	.	20.00000-	20.00000-	.
A	7	C2002	EQ	10.00000-	.	10.00000-	10.00000-	.
A	8	C1003	EQ	25.00000-	.	25.00000-	25.00000-	.
A	9	C2003	EQ	20.00000-	.	20.00000-	20.00000-	.
A	10	C1004	EQ	.	.	.	.	.
A	11	C2004	EQ	.	.	.	.	.
A	12	C1005	EQ	18.00000-	.	18.00000-	18.00000-	.
A	13	C2005	EQ	8.00000-	.	8.00000-	8.00000-	.
	14	C1006	EQ	.	.	.	.	3.00000
	15	C2006	EQ	.	.	.	.	4.50000
	16	C1007	EQ	10.00000-	.	10.00000-	10.00000-	3.00000
	17	C2007	EQ	5.00000-	.	5.00000-	5.00000-	4.50000
	18	R1005	UL	.	.	NONE	.	23.00000-
	19	R2005	UL	.	.	NONE	.	10.00000-
	20	R1006	BS	21.00000-	21.00000	NONE	.	.
	21	R2006	BS	26.00000-	26.00000	NONE	.	.

EXECUTOR. MPS/360 V2-M8

SECTION 2 - COLUMNS

	NUMBER	BL .COLUMN.	AT	BV ...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
	22	D1001	BS	24.00000	1.00000	.	30.00000	.
	23	D2001	BS	14.00000	2.50000	.	30.00000	.
	24	R1003	UL	35.00000	20.00000	2.00000	35.00000	20.00000
	25	R2003	UL	35.00000	10.00000	1.00000	35.00000	10.00000
	26	D1004	BS	65.00000	.	.	NONE	.
	27	D2004	BS	40.00000	.	.	NONE	.
	28	R1005	BS	50.00000	23.00000	2.00000	NONE	.
	29	R2005	BS	50.00000	10.00000	1.00000	NONE	.
	30	S005	UL	50.00000	.	.	50.00000	33.00000
	31	D1006	BS	9.00000	3.00000	.	NONE	.
	32	D2006	BS	4.00000	4.50000	.	NONE	.
A	33	S006	UL	30.00000	.	.	30.00000	.
	34	Q1001002	LL	1.00000	.	1.00000	NONE	1.00000-
	35	Q2001002	LL	1.00000	.	1.00000	NONE	2.50000-
	36	Q1002004	BS	46.00000	.	1.00000	NONE	.
	37	Q2002004	BS	31.00000	.	1.00000	NONE	.
	38	Q1003002	BS	25.00000	.	1.00000	NONE	.
	39	Q2003002	BS	20.00000	.	1.00000	NONE	.
	40	Q1005004	BS	19.00000	.	1.00000	NONE	.
	41	Q2005004	BS	9.00000	.	1.00000	NONE	.
	42	Q1006005	LL	1.00000	.	1.00000	NONE	3.00000-
	43	Q2006005	LL	1.00000	.	1.00000	NONE	4.50000-
	44	Q1007006	BS	10.00000	.	1.00000	NONE	.
	45	Q2007006	BS	5.00000	.	1.00000	NONE	.

NOTE THE FOLLOWING CHARACTERS ARE EQUIVALENT FOR THIS RUN:
% —— (, a —— ; □ ——)

FIGURE A-10b

MPS MINIMUM COBJ SOLUTION

SOLUTION %OPTIMAL□

TIME # 0.59 MINS. ITERATION NUMBER # 16

...NAME...	...ACTIVITY...		DEFINED AS		
FUNCTIONAL	9.00000	CC	COBJ	+	1.00000
RESTRAINTS			RUN4		
BOUNDS....			BD4		

SECTION 1 - ROWS

	NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT.	..UPPER LIMIT.	.DUAL ACTIVITY
	1	BOBJ	BS	925.00000	925.00000- CB	NONE	NONE	.
	2	COBJ	BS	8.00000	9.00000-	NONE	NONE	1.00000
	3	NOBJ	BS	917.00000	916.00000- CN	NONE	NONE	.
A	4	C1001	EQ	25.00000-	.	25.00000-	25.00000-	.
A	5	C2001	EQ	15.00000-	.	15.00000-	15.00000-	.
A	6	C1002	EQ	20.00000-	.	20.00000-	20.00000-	.
A	7	C2002	EQ	10.00000-	.	10.00000-	10.00000-	.
A	8	C1003	EQ	25.00000-	.	25.00000-	25.00000-	.
A	9	C2003	EQ	20.00000-	.	20.00000-	20.00000-	.
A	10	C1004	EQ	.	.	.	.	.
A	11	C2004	EQ	.	.	.	.	.
A	12	C1005	EQ	18.00000-	.	18.00000-	18.00000-	.
A	13	C2005	EQ	8.00000-	.	8.00000-	8.00000-	.
A	14	C1006	EQ	.	.	.	.	.
A	15	C2006	EQ	.	.	.	.	.
A	16	C1007	EQ	10.00000-	.	10.00000-	10.00000-	.
A	17	C2007	EQ	5.00000-	.	5.00000-	5.00000-	.
	18	B1005	UL	.	.	NONE	.	4.00000
	19	B2005	BS	1.00000-	1.00000	NONE	.	.
	20	B1006	UL	.	.	NONE	.	2.00000
	21	B2006	BS	.	.	NONE	.	.

SECTION 2 - COLUMNS

	NUMBER	CL .COLUMN.	AT	CV ...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
	22	D1001	BS	24.00000	.	.	30.00000	.
	23	D2001	BS	14.00000	.	.	30.00000	.
A	24	R1003	UL	35.00000	.	2.00000	35.00000	.
	25	R2003	BS	11.00000	.	1.00000	35.00000	.
	26	D1004	BS	49.00000	.	.	NONE	.
	27	D2004	BS	69.00000	.	.	NONE	.
	28	R1005	LL	2.00000	.	2.00000	NONE	4.00000
A	29	R2005	LL	1.00000	.	1.00000	NONE	.
	30	S005	BS	2.00000	4.00000	.	50.00000	.
	31	D1006	LL	.	.	.	NONE	2.00000
A	32	D2006	LL	.	.	.	NONE	.
	33	S006	BS	.	2.00000	.	30.00000	.
A	34	Q1001002	LL	1.00000	.	1.00000	NONE	.
A	35	Q2001002	LL	1.00000	.	1.00000	NONE	.
	36	Q1002004	BS	22.00000	.	1.00000	NONE	.
	37	Q2002004	BS	55.00000	.	1.00000	NONE	.
A	38	Q1003002	LL	1.00000	.	1.00000	NONE	.
	39	Q2003002	BS	44.00000	.	1.00000	NONE	.
	40	Q1005004	BS	27.00000	.	1.00000	NONE	.
	41	Q2005004	BS	14.00000	.	1.00000	NONE	.
	42	Q1006005	BS	10.00000	.	'.00000	NONE	.
	43	Q2006005	BS	5.00000	.	1.00000	NONE	.
	44	Q1007006	BS	10.00000	.	1.00000	NONE	.
	45	Q2007006	BS	5.00000	.	1.00000	NONE	.

NOTE: THE FOLLOWING CHARACTERS ARE EQUIVALENT FOR THIS RUN:

% —— (, □ —— ; □ ——)

FIGURE A-10c

MPS MAXIMUM NOBJ SOLUTION

EXECUTOR. MPS/360 V2-M8

SOLUTION %OPTIMAL□

TIME # 0.79 MINS. ITERATION NUMBER # 21

...NAME...	...ACTIVITY...		DEFINED AS		
FUNCTIONAL	2585.00000	NN	NOBJ	-	1.00000
RESTRAINTS			RUN4		
BOUNDS....			BD4		

SECTION 1 - ROWS

	NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY		..LOWER LIMIT.	..UPPER LIMIT.	.DUAL ACTIVITY
	1	BOBJ	BS	2804.00000	2804.00000	NB	NONE	NONE	.
	2	COBJ	BS	218.00000	219.00000		NONE	NONE	.
	3	NOBJ	BS	2586.00000	2585.00000	NC	NONE	NONE	1.00000
	4	C1001	EQ	25.00000-	.		25.00000-	25.00000-	1.00000
	5	C2001	EQ	15.00000-	.		15.00000-	15.00000-	2.50000
A	6	C1002	EQ	20.00000-	.		20.00000-	20.00000-	.
A	7	C2002	EQ	10.00000-	.		10.00000-	10.00000-	.
A	8	C1003	EQ	25.00000-	.		25.00000-	25.00000-	.
A	9	C2003	EQ	20.00000-	.		20.00000-	20.00000-	.
A	10	C1004	EQ	.	.		.	.	.
A	11	C2004	EQ	.	.		.	.	.
A	12	C1005	EQ	18.00000-	.		18.00000-	18.00000-	.
A	13	C2005	EQ	8.00000-	.		8.00000-	8.00000-	.
	14	C1006	EQ	.	.		.	.	1.00000
	15	C2006	EQ	.	.		.	.	4.50000
	16	C1007	EQ	10.00000-	.		10.00000-	10.00000-	1.00000
	17	C2007	EQ	5.00000-	.		5.00000-	5.00000-	4.50000
	18	B1005	UL	.	.		NONE	.	23.00000-
	19	B2005	UL	.	.		NONE	.	10.00000-
	20	B1006	UL	.	.		NONE	.	2.00000-
	21	B2006	BS	5.00000-	5.00000		NONE	.	.

SECTION 2 - COLUMNS

NUMBER	.COLUMN. NL	AT	...ACTIVITY... NV	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
22	D1001	BS	24.00000	1.00000	.	30.00000	.
23	D2001	BS	14.00000	2.50000	.	30.00000	.
24	R1003	UL	35.00000	20.00000	2.00000	35.00000	20.00000
25	R2003	UL	35.00000	10.00000	1.00000	35.00000	10.00000
26	D1004	BS	65.00000	.	.	NONE	.
27	D2004	BS	40.00000	.	.	NONE	.
28	R1005	BS	50.00000	23.00000	2.00000	NONE	.
29	R2005	BS	50.00000	10.00000	1.00000	NONE	.
30	S005	UL	50.00000	4.00000-	.	50.00000	29.00000
31	D1006	BS	9.00000	3.00000	.	NONE	.
32	D2006	BS	4.00000	4.50000	.	NONE	.
33	S006	BS	9.00000	2.00000-	.	30.00000	.
34	Q1001002	LL	1.00000	.	1.00000	NONE	1.00000-
35	Q2001002	LL	1.00000	.	1.00000	NONE	2.50000-
36	Q1002004	BS	46.00000	.	1.00000	NONE	.
37	Q2002004	BS	31.00000	.	1.00000	NONE	.
38	Q1003002	BS	25.00000	.	1.00000	NONE	.
39	Q2003002	BS	20.00000	.	1.00000	NONE	.
40	Q1005004	BS	19.00000	.	1.00000	NONE	.
41	Q2005004	BS	9.00000	.	1.00000	NONE	.
42	Q1006005	LL	1.00000	.	1.00000	NONE	1.00000-
43	Q2006005	LL	1.00000	.	1.00000	NONE	4.50000-
44	Q1007006	BS	10.00000	.	1.00000	NONE	.
45	Q2007006	BS	5.00000	.	1.00000	NONE	.

NOTE: THE FOLLOWING CHARACTERS ARE EQUIVALENT FOR THIS RUN:

% —— (, □ —— ; ⌑ ——)

(d) Variable Value Column
[BV]

(2) Minimum COBJ Solution

(a) Objective Function Name and Value
[CC]

(b) Negative of other Objective Function Values
[CB] , [CN]

(c) Variable Name List Column
[CL]

(d) Variable Value Column
[CV]

(3) Maximum NOBJ Solution

(a) Objective Function Name and Value
[NN]

(b) Negative of other Objective Function Values
[NB] , [NC]

(c) Variable Name List Column
[NL]

(d) Variable Value Column
[NV]

b. Data Interpretation. Output data from the model can be used to assist in decisions with respect to all component operation policies (operating variable values) and proposed component sizes (capacity variable values). Each decision is made considering the importance of a particular objective function in the eyes of the decision-maker. For example, two decision-makers might differ as to the relative importance of BOBJ, COBJ and NOBJ. Table A-3 shows the example HYDRO5 results for nodes 003, 005 and 006, an existing reservoir, a proposed reservoir and a proposed diversion, respectively.

In this example it is interesting to note that the definitions of BOBJ and COBJ are such that there is more than one solution (group of values assigned to variables) giving an optimum value of these functions. The IBM MPS software is arranged to highlight these alternate solutions (by an A in the extreme left-hand columns of Figure A-10) whenever they occur. In any properly formulated linear programming problem no unique solution is guaranteed; only the value of the objective function being optimized will be unique, though it exists for possibly more than one solution to the problem.

TABLE A-3

Selected Example Results

Item of Interest	Value at Max. BOBJ	Value at Min. COBJ	Value at Max. NOBJ
BOBJ[1]	(2804)	1175, 925	2804
COBJ[1]	219, 261[3]	(9)	219
NOBJ[1]	2585, 2543	1166, 916	(2585)
R1003[2]	35	35	35
R2003	35	35, 11	35
R1005	50	2	50
R2005	50	2, 1	50
S005	50	2	50
D1006	9	0	9
D2006	4	0	4
S006	9, 30	0	9

[1] Arbitrary but consistent (among BOBJ, COBJ and NOBJ) units (optimum appears in parenthesis).

[2] Variables expressed in arbitrary volume units.

[3] Where pairs of table entries occur, second entry denotes IBM MPS alternate solution giving same objective function value.

APPENDIX B - OPTIMIZATION MODEL RAW INPUT DATA

APPENDIX B

OPTIMIZATION MODEL RAW INPUT DATA

Table B-1, which follows this brief discussion, constitutes the remainder of this appendix. The table contains data which was converted to the MPS format mentioned in Appendix A for the optimization model run. The nodes are grouped into the following 5 types which appear in Table B-1 in numerical order:

Ordinary Nodes (ON) - Only those ordinary nodes (junctions for which there are no Rtj or Dtj variables) having nonzero local inflows are listed. The negative inflows are values taken to adjust the total system flows to coincide with known gaging records mentioned in Part VI.

Existing Reservoirs (ER) - All existing reservoirs were assumed to have a fixed operating policy such that their operating variables Rtj were placed on the RHS of Ctj equations. Lack of data on ER capacities made this procedure necessary.

Proposed Reservoir Diversions (PRD) - For the PRDs marked with an asterisk (*), the capacity upper bounds were assumed to be 20,000 acre-feet where no capacity data was available.

Existing Diversion (ED) - For all of these structures Qij was taken as zero.

Proposed Diversions (PD) - Note that one of the PDs is a proposed branch, namely 557209,

The local inflow data is presented as a set of average annual value in 10^3 acre-feet. As Part IX mentions, the actual run was made with 65% of these values to simulate a low-flow condition. The 2 seasons of the model (NS=2) are the wet season (t = 1) and the dry season (t = 2). Coefficient (bxvj and cxvj) and constant (cxfj) data are expressed in units of 10^3 dollars.

In the remarks section of Table B-1, the following two abbreviations are used: LB (lower bound), UB (upper bound). Also in this section fixed values are denoted such as S = 765.00 for PRD 535.

TABLE B-1
TABULATED RAW INPUT DATA
FOR OPTIMIZATION MODEL

		LOCAL INFLOW					
NUMBER	NODE TYPE	t = 1	t = 2	bxvi	cxvj	cxfj	REMARKS
001	ER	4.48	6.26	0	0	0	R1=R2
002	ER	1.39	0.26	0	0	0	R1=R2
003	ER	9.35	22.64	0	0	0	R1=R2
004	ER	3.04	0	0	0	0	R1=R2
005	ER	0.73	0	0	0	0	R1=R2
006	ER	0.52	0	0	0	0	R1=R2
007	ER	0.05	0.18	0	0	0	R1=R2
008	ER	0.09	0.18	0	0	0	R1=R2
009	ER	0.13	3.86	0	0	0	R1=R2
010	ER	0.1	1.24	0	0	0	R1=R2
011	ER	0.05	0.11	0	0	0	R1=R2
012	ER	0.1	3.68	0	0	0	R1=R2
013	ER	0.11	0.24	0	0	0	R1=R2
014	ER	0.05	0.1	0	0	0	R1=R2
015	ER	5.70	35.51	0	0	0	R1=R2
016	ER	0.25	1.53	0	0	0	R1=R2
017	ER	0	0	0	0	0	UBQ1017060=35.5, UBQ2017060=86.4
018	ER	3.29	2.97	0	0	0	R1=R2
019	ER	1.19	1.16	0	0	0	R1=R2
020	ER	18.66	16.83	0	0	0	R1=R2
021	ER	7.34	0.18	0	0	0	R1=R2
022	ER	0.1	0.01	0	0	0	R1=R2
023	ER	17.59	0.12	0	0	0	R1=R2

TABLE B-1 (CONT.)

NUMBER	NODE TYPE	LOCAL INFLOW		bxvi	cxvj	cxfj	REMARKS
		t = 1	t = 2				
024	ER	4.79	0.43	0	0	0	R1=R2
025	ER	5.86	5.28	0	0	0	R1=R2
026	ER	0.92	0.83	0	0	0	R1=R2
027	ER	0.38	0	0	0	0	R1=R2
034	ON	0	-78.30	0	0	0	
035	ON	0	-77.52	0	0	0	
038	ED	0	0	0	0	0	Q2038614=96.9
039	ED	0	0	0	0	0	Q2039004=96.8
043	ED	0	0	0	0	0	Q2043047=111.5
044	ED	0	0	0	0	0	Q2044617=69.8
046	ED	0	0	0	0	0	Q2046047=143.3
051	ON	0	-284.88	0	0	0	
101	ER	5.57	6.51	0	0	0	R1=R2
102	ER	7.9	3	0	0	0	R1=R2
103	ER	1.86	0.34	0	0	0	R1=R2
104	ER	1.29	0.23	0	0	0	R1=R2
105	ER	0.94	0.04	0	0	0	R1=R2
106	ER	0.04	0.01	0	0	0	R1=R2
107	ER	25.54	0	0	0	0	R1-R2=50.49, R2-R1=-50.49, UBQ11107229=22, UBQ12107229=52.90
108	ER	0.07	0.01	0	0	0	R1=R2
109	ER	1.35	0.17	0	0	0	R1=R2
110	ER	0.05	0.01	0	0	0	R1=R2
111	ER	0.12	0.01	0	0	0	R1=R2

TABLE B-I (CONT.)

NUMBER	NODE TYPE	LOCAL INFLOW		bxvi	cxvj	cxfj	REMARKS
		t = 1	t = 2				
112	ER	0.53	0.07	0	0	0	R1=R2
113	ER	0.01	0.01	0	0	0	R1=R2
114	ER	2.40	0.28	0	0	0	R1=R2
115	ER	1.09	0.14	0	0	0	R1=R2
116	ER	0.05	0	0	0	0	R1=R2
117	ER	0	0	0	0	0	R1=R2
118	ER	0.04	0.01	0	0	0	R1=R2
119	ER	0.28	0.07	0	0	0	R1=R2
120	ER	0.05	0.02	0	0	0	R1=R2
121	ER	0.08	0.01	0	0	0	R1=R2
122	ER	0.04	0.01	0	0	0	R1=R2
123	ER	0.09	0	0	0	0	R1=R2
124	ER	0.19	0.02	0	0	0	R1=R2
125	ER	0.26	0.03	0	0	0	R1=R2
126	ER	0.02	0	0	0	0	R1=R2
127	ER	0.37	0.10	0	0	0	R1=R2
128	ER	0.07	0.12	0	0	0	R1=R2
129	ER	0.07	0.12	0	0	0	R1=R2
130	ER	0.64	0.54	0	0	0	R1=R2
131	ER	0.12	0.01	0	0	0	R1=R2
132	ER	0.10	0.02	0	0	0	R1=R2
133	ER	0.01	0	0	0	0	R1=R2
134	ER	0.02	0	0	0	0	R1=R2

TABLE B-1 (CONT.)

NUMBER	NODE TYPE	LOCAL INFLOW t = 1	LOCAL INFLOW t = 2	bxvi	cxvj	cxfj	REMARKS
135	ER	0.13	0.03	0	0	0	R1=R2
136	ER	0.04	0.01	0	0	0	R1=R2
137	ER	0.14	1.26	0	0	0	R1=R2
138	ER	5.30	11.18	0	0	0	R1=R2
139	ER	0.13	0.02	0	0	0	R1=R2
140	ER	0.07	0.01	0	0	0	R1=R2
141	ER	0	11.96	0	0	0	R1=R2
142	ER	0.06	0.01	0	0	0	R1=R2
143	ER	0.22	0.04	0	0	0	R1=R2
144	ER	1.04	0.19	0	0	0	R1=R2
145	ER	2.63	0.48	0	0	0	R1=R2
146	ER	0.58	0.11	0	0	0	R1=R2
147	ER	0.01	0	0	0	0	R1=R2
148	ER	0.02	0.01	0	0	0	R1=R2
149	ER	0.10	0.01	0	0	0	R1=R2
150	ER	0	0.04	0	0	0	R1=R2
151	ER	0.42	0	0	0	0	R1=R2
152	ER	0.12	0.1	0	0	0	R1=R2
153	ER	0.56	0.1	0	0	0	R1=R2
154	ER	0.2	0	0	0	0	R1=R2
155	ER	0.12	0	0	0	0	R1=R2
156	ER	0.09	0.01	0	0	0	R1=R2
157	ER	0	0	0	0	0	R1=R2

TABLE B-I (CONT.)

NUMBER	NODE TYPE	LOCAL INFLOW		bxvi	cxvj	cxfj	REMARKS
		t = 1	t = 2				
158	ER	2.	0.66	0	0	0	R1=R2
159	ER	0.04	0.01	0	0	0	R1=R2
160	ER	0.02	0.05	0	0	0	R1=R2
161	ER	0	0	0	0	0	R1=R2
162	ER	0	0	0	0	0	R1=R2
163	ER	0.01	0	0	0	0	R1=R2
164	ER	0.26	0.1	0	0	0	R1=R2
165	ER	0.06	0.02	0	0	0	R1=R2
166	ER	0.22	0.1	0	0	0	R1=R2
167	ER	0.28	0.11	0	0	0	R1=R2
168	ER	0.04	0.02	0	0	0	R1=R2
169	ER	0.04	0.1	0	0	0	R1=R2
170	ER	0.25	0.09	0	0	0	R1=R2
171	ER	1.06	0.38	0	0	0	R1=R2
172	ER	0.07	0.02	0	0	0	R1=R2
173	ER	0.03	0.05	0	0	0	R1=R2
174	ER	50.93	0	0	0	0	R1=R2
175	ER	0.45	0.15	0	0	0	R1=R2
176	ER	0	0	0	0	0	R1=R2
177	ER	0.83	0.27	0	0	0	R1=R2
178	ER	0.25	0.08	0	0	0	R1=R2
179	ER	0.17	0.06	0	0	0	R1=R2
180	ER	0.24	0.01	0	0	0	R1=R2

TABLE B-1 (CONT.)

NUMBER	NODE TYPE	LOCAL INFLOW t = 1	LOCAL INFLOW t = 2	bxvi	cxvj	cxfj	REMARKS
181	ER	0.38	0.03	0	0	0	R1=R2
182	ER	0.20	0.06	0	0	0	R1=R2
183	ER	0	0	0	0	0	R1-R2=1.8 R2-R1=-1.8
184	ER	0.02	0.01	0	0	0	R1=R2
185	ER	0.01	0	0	0	0	R1=R2
186	ER	0.01	0.01	0	0	0	R1=R2
187	ER	0.01	0	0	0	0	R1=R2
188	ER	0.03	0.01	0	0	0	R1=R2
189	ER	0.03	0.01	0	0	0	R1=R2
190	ER	0.02	0.01	0	0	0	R1=R2
191	ER	0.28	0.01	0	0	0	R1=R2
192	ER	0.44	0.02	0	0	0	R1=R2
193	ER	14.88	7.69	0	0	0	R1=R2
194	ER	2.03	0.48	0	0	0	R1=R2
195	ER	0.07	0.02	0	0	0	R1=R2
196	ER	0.65	0.15	0	0	0	R1=R2
197	ER	0.03	0.01	0	0	0	R1=R2
198	ER	0	0	0	0	0	R1=R2
199	ER	0.14	0.03	0	0	0	R1=R2
200	ER	50.93	0	0	0	0	LBQ1200323=22.0, LBQ2200323=52.90
201	ER	0.1	0.02	0	0	0	R1=R2
202	ER	0.07	0.02	0	0	0	R1=R2
203	ER	0.01	0	0	0	0	R1=R2

TABLE B-1 (CONT.)

NUMBER	NODE TYPE	LOCAL INFLOW t = 1	LOCAL INFLOW t = 2	bxvi	cxvj	cxfj	REMARKS
204	ER	0.06	0.02	0	0	0	R1=R2
205	ER	0.01	0	0	0	0	R1=R2
206	ER	0.14	0.06	0	0	0	R1=R2
207	ER	0.01	0.05	0	0	0	R1=R2
208	ER	1.24	0.4	0	0	0	R1=R2
209	ER	1.09	0.36	0	0	0	R1=R2
210	ER	1.24	0.4	0	0	0	R1=R2
211	ER	0.4	0.13	0	0	0	R1=R2
212	ER	0.39	0.13	0	0	0	R1=R2
213	ER	0.32	0.1	0	0	0	R1=R2
214	ER	0	0	0	0	0	R1=R2
215	ER	1.40	0.46	0	0	0	R1=R2
216	ER	0.12	0.04	0	0	0	R1=R2
217	ER	0.51	0.17	0	0	0	R1=R2
220	ED	0	150	0	0	0	Q2220602=149.1
226	ON	0	-19.66	0	0	0	
251	ED	0	0	0	0	0	Q2251440=83.57
261	ED	0	0	0	0	0	Q2261146=4.56
270	ON	0	-38.81	0	0	0	
291	ED	0	0	0	0	0	Q2291292=31.93
314	ED	78.22	32.61	0	0	0	Q21314313=8.84
320	ED	0	0	0	0	0	Q2320322=1
401	ER	4.4	4	0	0	0	R1=R2

TABLE B-1 (CONT.)

NUMBER	NODE TYPE	LOCAL INFLOW t = 1	LOCAL INFLOW t = 2	bxvi	cxvj	cxfj	REMARKS
402	ER	11.68	10.53	0	0	0	R1=R2
403	ER	18.42	0.46	0	0	0	R1=R2
404	ER	14	1.4	0	0	0	R1=R2
405	ER	6.92	0.63	0	0	0	R1=R2
406	ER	36.94	11.98	0	0	0	R1=R2
407	ER	0.89	2.91	0	0	0	R1=R2
408	ER	14.33	1.30	0	0	0	R1=R2
409	ER	0.82	0.17	0	0	0	R1=R2
410	ER	11.66	2.45	0	0	0	R1=R2
411	ER	0.14	0.06	0	0	0	R1=R2
412	ER	0.6	0.27	0	0	0	R1=R2
413	ER	0	0	0	0	0	LBQ1413435=2587.25, LBQ2413435=1656.79
414	ER	0.09	0.03	0	0	0	R1=R2
415	ER	0.23	0.07	0	0	0	R1=R2
420	ON	2176.85	2454.75	0	0	0	
422	ON	40.3	65.7	0	0	0	
428	ON	131.26	159.14	0	0	0	
433	ON	56.58	100.72	0	0	0	
441	ED	0	0	0	0	0	Q2441337=30.35
488	ON	35.35	11.24	0	0	0	
530	PRD	0	0	15	1.67	25.97	UBS=17.96,UBD2=14.04
531	PRD						NOT MODELED IN SYSTEM
532	PRD	0	0	15	1.67	25.97	UBS=823.9, UBD2=9
533	PRD	10	8	15	1.67	25.97	UBS=15.82, UBD2=10.8

TABLE B-1 (CONT.)

NUMBER	NODE TYPE	LOCAL INFLOW t = 1	t = 2	bxvi	cxvj	cxfj	REMARKS
534	PRD	1.17	6.14	15	1.67	25.97	UBS=13.28
535	PRD	20	0	10.23	10.77	0	S=765
536	PD	20	0	15	10.7	0	UBD1=0,UBD2=1.5
537	PRD	16.07	14.53	15	1.67	25.97	UBS=13.1,UBD2=13.1
538	PRD	0.2	0.05	15	1.67	25.97	UBS=3.51,UBD2=3.51
541	PRD	1.62	0.42	20	4.66	0	UBS=200,UBD2=200
542	PRD	0	0	15.6	9.82	0	S=573.6,D2=225.9
543	PRD	10	100.52	2.08	1.1	0	S=8,750
544	PRD	0.31	0.66	15	3.98	0	UBS=65,UBD2=21.06
* 545	PRD	0	0	15	1.67	25.97	UBS=20
546	PRD	1.82	0.23	15	1.67	25.97	UBS=20.97,UBD2=20.97
547	PRD	0.03	0.14	21.37	8.66	0	UBS=7.23,UBD2=7.23
* 548	PRD	0.96	0.81	15	1.67	25.97	UBS=20
549	PRD	0.46	0.21	15	1.67	25.97	UBS=3.98,UBD2=3.98
550	PRD	0.83	0.15	15	2.69	0	UBS=17.5
551	PRD	0.3	0.05	15	10.42	0	UBS=6.9
552	PRD	3.61	1.39	15	1.67	25.97	UBS=12,UBD2=2.62
553	PRD	2.27	0.75	15	1.69	0	UBS=371
554	PRD	4.66	1.52	15	1.67	25.97	UBS=56.8
555	PRD	5.30	1.24	15	11.8	0	UBS=21
556	PRD	4.35	1.02	15	2.37	0	UBS=25
557	PD	0	0	15	10.7	0	UBD1=0,Q2557209=30
558	PD	0	0	0	0	0	D1=0,D2=127, Q2558246=18

TABLE B-1 (CONT.)

NUMBER	NODE TYPE	LOCAL INFLOW		bxvi	cxvj	cxfj	REMARKS
		t = 1	t = 2				
*601	PRD	30.4	35.66	15	1.67	25.97	UBS=20
602	PRD	13.28	11.46	15	1.67	25.97	UBS=78.93, UBD2=45.86
603	PRD	58.28	49.69	15	1.67	25.97	UBS=209 13, UBD2=65.52
604	PRD	2.03	3.71	15	1.67	25.97	UBS=231.89, UBD2=50.88
605	PRD	6.54	12.03	15	1.67	25.97	UBS=39, UBD2=39
606	PRD	2.41	6.21	15	1.67	25.97	UBS=84.8 UBD2=81.06
607	PRD	1.35	3.49	15	1.67	25.97	UBS=35.57, UBD2=11.7
608	PRD	2.82	5.11	15	1.67	25.97	UBS=56.38, UBD2=1.87
609	PRD	4.08	7.42	15	1.67	25.97	UBS=120.31, UBD2=3.51
610	PRD	7.11	12.95	15	1.67	25.97	UBS=18.72, UBD2=20.52
611	PRD	1.49	3.4	15	1.67	25.97	UBS=47.56, UBD2=23.4
612	PRD	2.93	4.62	15	1.67	25.97	UBS=248.06, UBD2=1.44
613	PRD	10.58	19.25	15	1.67	25.97	UBS=62.69
614	PRD	0	0	15	1.67	25.97	UBS=30
615	PRD	39.13	98.32	15	1.67	25.97	UBS=204.39, UBD2=1.26
616	PRD	29.17	123.4	15	1.67	25.97	UBS=136.13, UBD2=14.04
617	PRD	20.6	141.76	15	1.67	25.97	UBS=3.05, UBD2=2.62
618	PRD	0	0	15	1.67	25.97	UBS=63.18, UBD2=21.29
619	PRD	0	0	15	1.67	25.97	UBS=81.6
620	PRD	23.81	164.11	15	1.67	25.97	UBS=54.07, UBD2=1.58
621	PRD	34.75	143.30	15	1.67	25.97	UBS=83.13, UBD2=1.58
622	PRD	4.01	16.9	15	1.67	25.97	UBS=54.28
623	PRD	12.44	52.34	15	1.67	25.97	UBS=171.12

TABLE B-1 (CONT.)

NUMBER	NODE TYPE	LOCAL INFLOW t = 1	LOCAL INFLOW t = 2	bxvi	cxvj	cxfj	REMARKS
* 624	PRD	4.62	24.07	15	1.67	25.97	UBS=20
* 701	PRD	0.29	0.07	15	1.67	25.97	UBS=20
* 702	PRD	0.18	0.05	15	1.67	25.97	UBS=20
* 801	PRD	0.57	0.14	15	1.67	25.97	UBS=20
802	PRD	0.82	0.27	15	1.67	25.97	UBS=2.39,UBD2=2.39
803	PRD	0.6	0.18	15	1.67	25.97	UBS=4.4,UBD2=4.4
* 804	PRD	0.77	0.25	15	1.67	25.97	UBS=20
* 805	PRD	0.66	0.26	15	1.67	25.97	UBS=20
806	PRD	2.78	0.98	15	1.67	25.97	UBS=9.17,UBD2=9.17
807	PRD	2.32	0.89	15	1.67	25.97	UBS=1.17,UBD2=1.17
808	PRD	2.79	1.02	15	1.67	25.97	UBS=3.98,UBD2=3.98
809	PRD	0.28	0.02	15	1.67	25.97	UBS=4.91,UBD2=4.91
810	PRD	0.07	0.02	15	1.67	25.97	UBS=6.64,UBD2=6.64
* 811	PRD	1.12	0.41	15	1.67	25.97	UBS=20
812	PRD	1.17	0.43	15	1.67	25.97	UBS=1.78,UBD2=1.78
813	PRD	0.22	0.07	15	1.67	25.97	UBS=6.65,UBD2=6.65
814	PRD	5.51	1.16	15	1.67	25.97	UBS=16.52,UBD2=16.52
815	PRD	0.08	0.03	15	1.67	25.97	UBS=371,UBD2=6.64
901	PRD	3.03	2	15	1.67	25.97	UBD2=1
902	PRD	5.08	3.08	15	1.67	25.97	UBD2=3.5
903	PRD	2	0.46	15	1.67	25.97	UBD2=3.4

APPENDIX C

LIST OF POTENTIAL PROJECTS

POTENTIAL PROJECTS

MWRB PROJECT NUMBER	COMPUTER MODEL NO.	DRAINAGE AREA	COUNTY	SITE NAME	STREAM NAME	LOCATION			DRAINAGE AREA SQ. MILES	PURPOSE	DAM		RESERVOIR		1970 COST EQUIV. IN $1000
						TWP.	RGE.	SEC.			HEIGHT IN FEET	CREST LENGTH FEET	NORMAL POOL AREA - ACRES	STORAGE ACRE FEET	
12	555	40N	VA	ROCK CR.	ROCK CR.	34N	36E			T	53		[illegible]	21,500	3,593
131	556	40N	VA	WILLOW CR.	WILLOW CR.	33N	36E	24	247	I, R, FWT	90	1,080	1,120	25,000	1,046
542		40N	VA	FRENCHMAN CR.		32N	35E			I					
549		400	VA	CHERRY CR.						I					
443		400	VA	ROBERTSON		28N	42E	25		I					
553		400	VA	SCHNEIDER DAM	HAWK CR.	29N	40E	9		I					
		400	VA	MIDWAY DAM PORCUPINE CR.		30N	41E								
	557	400	VA	FT. PECK UP BEAVER CR.											
768		40M	VA	LARB CR.						I					
101	553	40M	PH	BEAVER CR.	BEAVER CR.	30N	32E			I, T	65	10,500	19,400	371,000	12,496
11	554	40M	PH	RESERVOIR # 1	BEAVER CR.	29N	32E			I	48			56,800	3,760
542		40M	PH	SACO DIVIDE PUMP		31N	34E			I					
4015	815	40M	PH	LITTLE WARM SPRING CR.		26N	26E								
4013	813	40M	PH	BIG WARM STREAM CR.		26N	24E								
4010	810	40M	PH	WILD HORSE CR.		27N	26E								

REFERENCE: SUMMARY OF POTENTIAL PROJECTS IN MONTANA

POTENTIAL PROJECTS

MWRB PROJECT NUMBER	COMPUTER MODEL NO.	DRAINAGE AREA	COUNTY	SITE NAME	STREAM NAME	LOCATION TWP.	LOCATION RGE.	LOCATION SEC.	DRAINAGE AREA SQ.MILES	PURPOSE	DAM HEIGHT IN FEET	DAM CREST LENGTH FEET	RESERVOIR NORMAL POOL AREA -ACRES	RESERVOIR STORAGE ACRE FEET	1970 COST EQUIV. IN $1000
168		40L	PH	STINKY DAM	EF STINKING WATER CR.	34N	33E	16		I	40	100			
100		40K	PH	PEA LAKE	NO. FK. WHITEWATER CR.	37N	31E			I					
15	552	40K	PH	WHITEWATER	WHITEWATER CR.	34N	32E			I	20			12,000	
232		40J	PH	BOWDOIN LAKE	[illegible]	30N	31E			I					
		40J	BL	BATTLE CR.	BATTLE CR.	33N	19E			T	84			110,000	7,330
175		40J	BL	CLEAR CR.	CLEAR CR.	30N	17W	26	77	I		380		3,200	891.2
18		40J	BL	COMMUNITY RNG.		34N	23E			I					
7		40J	BL	DOWEN	BATTLE CR.	36N	18E			I					1,435
310		40J	BL	EIGHT MILE CR.						I					
309		40J	BL	GUETZGEN DAM		32N	19E	35		T					
311		40J	BL	KOPP DAM	SAVOY CR.	32N	24E	1		I					
13		40J	BL	THIRTY MILE CR.	THIRTY MILE CR.	33N	22E			T	85			26,500	5,969.6
14		40J	BL	WAYNE CR.	WAYNE CR.	32N	24E			T	80			21,000	7,599.8
172		40J	BL	WOODY ISLAND CR.	WOODY ISLAND CR.	37N	25E			I					
4001	801	40J	BL	THREE MILE CR. # 1		31N	23E								
4004	804	40J	BL	FIFTEEN MILE CR. #1		30N	23E								
4002	802	40J	BL	WHITE BEAR CR. # 1		30N	24E								
16B	551	40J	BL	BATTLE CR.	BATTLE CR.	36N	18E	9		I	54	1,550	1,220	12,200	
16A	550	40J	HI	LODGE CR.	LODGE CR.	36N	16E	14	797	I	52	1,543		17,500	830

REFERENCE: SUMMARY OF POTENTIAL PROJECTS IN MONTANA

POTENTIAL PROJECTS

MWRB PROJECT NUMBER	COMPUTER MODEL NO.	DRAINAGE AREA	COUNTY	SITE NAME	STREAM NAME	LOCATION			DRAINAGE AREA SQ. MILES	PURPOSE	DAM		RESERVOIR		1970 COST EQUIV. IN $1,000
						TWP.	RGE.	SEC.			HEIGHT IN FEET	CREST LENGTH FEET	NORMAL POOL AREA - ACRES	STORAGE ACRE FEET	
55	547	40J	HI	BEAVER CR.	BEAVER CR.	31N	15E	25	78.9	I	97.5	2,680	178	7,230	1,012.4
394	548	40J	HI	BOX ELDER	LITTLE BOX ELDER STO.	32N	17E	17		I					
56		40J	HI	BULL HOOK CR.	BULL HOOK CR.	32N	16E			I	108			10,600	
176		40J	HI	BURNS	BLACK COULEE	31N	10E	31		I					
346		40J	HI	RED ROCK CR.	RED ROCK COULEE	34N	15E			I					
59		40J	HI	THIBEDEAU LAKE	LOHMANS COULEE	35N	16E			I					
17		40J	BL	15 MILE CR.	15 MILE CR.	34N	20E	24		I					
308		40J	BL	3 MILE STORAGE	3 MILE CR.	32N	18E	24		I					
301	549	40J	BL	SAVOY CR.		32N	24E		48.2						
22		40EJ	FE	ROCKY POINT	MISSOURI RIVER	21N	25E	5	41,330	TNP	137	4,500	20,200	1,112,800	
4014	814	40EJ	BL	LITTLE SUCTION CR. #1		26N	22E								
	543	40EJ	BL	HIGH COW	MISSOURI RIVER	24N	22E				365	I		3,750,000	275,700
4005	805	401	BL	PEOPLES CR. # 2		28N	24E								
4003	803	401	PH	PEOPLES CR. # 1		30N	26E								
4006	806	401	BL	PEOPLES CR. # 4		29N	22E								
4007	807	401	BL	PEOPLES CR. # 3		28N	23E								
4009	809	401	BL	DUCK LAKE # 1		27N	22E								

REFERENCE: SUMMARY OF POTENTIAL PROJECTS IN MONTANA

POTENTIAL PROJECTS

MWRB PROJECT NUMBER	COMPUTER MODEL NO.	DRAINAGE AREA	COUNTY	SITE NAME	STREAM NAME	LOCATION			DRAINAGE AREA SQ. MILES	PURPOSE	DAM		RESERVOIR		1970 COST EQUIV. IN $1000
						TWP.	RGE.	SEC.			HEIGHT IN FEET	CREST LENGTH FEET	NORMAL POOL AREA - ACRES	STORAGE ACRE FEET	
4011	811	401	BL	LITTLE PEOPLES CR. #1		27N	23E								
4012	812	401	BL	LODGE POLE CR. # 1		27N	24E								
4008	808	401	BL	LITTLE ROCKY CR. #1		28N	24E								
312		41T	BL	ANDERSON		26N	19E	33		I					
1		41T	BL	BEARPAW	MISSOURI RIVER	23N	19E	19	39,500	I	109	2,320	7,900	210,600	
17		41T	FE	ILIAD	MISSOURI RIVER	22N	15E	3	36,070	TNP	215	2,955	41,380	3,037,000	
16		41T	CH	HOLE-IN-THE-WALL	MISSOURI RIVER					I	90				
9		41T	CH	EAGLE BUTTE	MISSOURI RIVER					I	75				
346		41P	HI	BLACK COULEE	BLACK COULEE	30N	9E			I					
53		41P	HI	MARIAS PUMPING	MARIAS RIVER	29N	8E	25		I					
128B	532	41P	GL	MARIAS RIVER	MARIAS RIVER RESERV.	31N	5W	2	2,610	I	305	5,400	11,412	823,990	47,451.2
372		41P	PO	CACTUS FLATS ROCK COULEE	ROCK COULEE	31N	3W			I					
371		41P	PO	MYWOOD DAM		28N	2E	14		I					
196		41P	PO	EBNER COMPANY DAM	ROCK COULEE	27N	1E	1		1					
		41P	TO	SHELBY WATER SHED											
		41P	L	MARIAS MILK UNIT		32N	2W								
	533	41P	PO	DRY FORK											

REFERENCE: SUMMARY OF POTENTIAL PROJECTS IN MONTANA

POTENTIAL PROJECTS

MWRB PROJECT NUMBER	COMPUTER MODEL NO.	DRAINAGE AREA	COUNTY	SITE NAME	STREAM NAME	LOCATION			DRAINAGE AREA SQ. MILES	PURPOSE	DAM		RESERVOIR		1970 COST EQUIV. IN $1000
						TWP.	RGE.	SEC.			HEIGHT IN FEET	CREST LENGTH FEET	NORMAL POOL AREA - ACRES	STORAGE ACRE FEET	
346		40F	HI	SPRING COULEE	SPRING COULEE	36N	12E			I					
2002	602	40F	GL	NO. FORK MILK RIVER #1		37N	10E								
2003	603	40F	GL	MILK RIVER # 1		37N	9E								
583		40G	HI	PATRICK	TRIB. OF MILK RIVER	36N	9E	15	25	I	8	1,120	25	348	
61	545	40G	HI	SAGE CR.	SAGE CR.	35N	9E	11		I					
358		40G	LI	JAMES DAM		34N	7E	34		I					
357		40G	LI	LAKELY DAM						I					
57	546	40H	HI	BIG SANDY CR.	BIG SANDY CR.					T				60,000	
628		40H	CH	BIG SANDY PUMPING											
60		40H	HI	GRAVEL COULEE	GRAVEL COULEE	30N	14E	12		I					
3001	701	40H	CH	BIG SANDY CR. # 1		28N	15E			T	84			60,000	
3002	702	40H	HI	BOX ELDER CR. # 1		29N	15E								
128B	541	40H	CH	LONESOME LAKE	12 MILE COULEE	29N	12E		250	I	49	930		200,000	
57	538	40H	CH	BIG SANDY CR.	BIG SANDY CR.	27N	13E	12		I				2,000	
10		41N	TO	LOST LAKE	W. FORK WILLOW CR.	34N	2W			I				98,300	
393		41N	TO	ROBERTS		88N	3W	24		I					

REFERENCE: SUMMARY OF POTENTIAL PROJECTS IN MONTANA

POTENTIAL PROJECTS

MWRB PROJECT NUMBER	COMPUTER MODEL NO.	DRAINAGE AREA	COUNTY	SITE NAME	STREAM NAME	LOCATION TWP.	LOCATION RGE.	LOCATION SEC.	DRAINAGE AREA SQ. MILES	PURPOSE	DAM HEIGHT IN FEET	DAM CREST LENGTH FEET	RESERVOIR NORMAL POOL AREA - ACRES	RESERVOIR STORAGE ACRE FEET	1970 COST EQUIV. IN $1000
25	544	41N	TO	WILLOW CR.	WILLOW CR.	34N	2E			I				65,000	
2		41Q	CH	CARTER	MISSOURI RIVER	22N	7E	8	24,475	PNT	155	2,485	3,410	215,100	
8	535	41Q	CH	FORT BENTON	MISSOURI RIVER	24N	8E	27	24,565	NPT	192			765,000	145,000
611	536	41Q	CH	FORT BENTON PUMPS	MISSOURI RIVER	24N	8E	27		I					
629	537	41Q	CH	HIGHWOOD CR.	HIGHWOOD CR.	21N	6E			I					
1		41M	PO	BADGER CR.	BADGER CR.	29N	11W			I				100,000	
2018	618	41M	PO	BIRCH CR.		31N	5W								
2017	617	41M	PO	ALKALI LAKE		31N	6W								
2019	619	41M	PO	BIRCH CR. # 2		30N	6W								
2024	624	41M	PO	BIRCH CR. # 3		28N	9W								
2023	623	41M	PO	BADGER CANYON		29N	12W								
701		41M	GL	GLACIER PARK STATION		31N	12W								
9		41M	GL	GUARDIPEE	TWO-MEDICINE CR.	33N	9W			I	60	600		38,000	
20		41M	GL	TWO-MEDICINE	TWO-MEDICINE	32N	12W			I	73	1,900		60,000	
21		41M	GL	TWO-MEDICINE LAKE	TWO-MEDICINE CR.										
2015	615	41M	GL	TWO-MEDICINE FORKS		31N	12W								

REFERENCE: SUMMARY OF POTENTIAL PROJECTS IN MONTANA

POTENTIAL PROJECTS

MWRB PROJECT NUMBER	COMPUTER MODEL NO.	DRAINAGE AREA	COUNTY	SITE NAME	STREAM NAME	LOCATION			DRAINAGE AREA SQ. MILES	PURPOSE	DAM		RESERVOIR		1970 COST EQUIV. IN $1,000
						TWP.	RGE.	SEC.			HEIGHT IN FEET	CREST LENGTH FEET	NORMAL POOL AREA - ACRES	STORAGE ACRE FEET	
2016	616	41M	GL	BADGER CR. # 1		31N	8W								
2022	622	41M	GL	BADGER CR. # 2		30N	10W								
2021	621	41M	GL	4 HORNS LAKE # 1		30N	9W								
2020	620	41M	GL	BLACKFEET CR. # 1		30N	8W								
691		41L	GL	CUT BANK	CUT BANK CR.	34N	8W			I	90			84,800	
5	530	41L	GL	CUT BANK DIVERSION	CUT BANK CR.	32N	5W			I				17,960	
18		41L	GL	SPRING LAKE	SPRING CR.	32N	8W			I				30,000	
2004	604	41L	GL	ROCKY COULEE # 1		36N	6W								
2005	605	41L	GL	ROCKY COULEE # 2		35N	6W								
2006	606	41L	GL	CUT BANK CR. # 1		34N	8W								
2007	607	41L	GL	CUT BANK CR. # 2		34N	9W								
2008	608	41L	GL	N.FORK CUT BANK CR. #1		33N	13W								
2009	609	41L	GL	S.FORK CUT BANK CR. #1		32N	13W								
2010	610	41L	GL	CUT FINGER LAKE		33N	10W								
2011	611	41L	GL	WILLOW CR. # 1		33N	9W								
2012	612	41L	GL	WILLOW CR. # 2		32N	10W								
2013	613	41L	GL	GUARDIPEE # 1		32N	9W								
2014	614	41L	GL	SPRING CR. # 1		32N	8W								

REFERENCE: SUMMARY OF POTENTIAL PROJECTS IN MONTANA

POTENTIAL PROJECTS

MWRB PROJECT NUMBER	COMPUTER MODEL NO.	DRAINAGE AREA	COUNTY	SITE NAME	STREAM NAME	LOCATION			DRAINAGE AREA SQ. MILES	PURPOSE	DAM		RESERVOIR		1970 COST EQUIV. IN $1000
						TWP.	RGE.	SEC.			HEIGHT IN FEET	CREST LENGTH FEET	NORMAL POOL AREA - ACRES	STORAGE ACRE FEET	
		41L	GL	BROWNING WATERSHED		32N	11W								
2001	601	40T	GL	ST. MARYS RIVER #1		37N	14W								
753 A88	531	40T	GL	WATERTON BELLY RIVER		37N	18E								
	901	40N	VA	PORCUPINE CK. 1	PORCUPINE CK.				729					59,200	
	902	40N	VA	PORCUPINE CK. 2	PORCUPINE CK.				616					64,860	
	903	40	VA	E. FORK PORCUPINE	E. FORK PORCUPINE				46					56,180	

REFERENCE: SUMMARY OF POTENTIAL PROJECTS IN MONTANA

APPENDIX D

MONTANA CONSERVANCY DISTRICT LAW

UNITED STATES OF AMERICA,) ss.
State of Montana)

I, FRANK MURRAY, Secretary of State of the State of Montana, do hereby certify that the following is a true and correct copy of Senate Bill No. 67, Chapter No. 100, Montana Session Laws of 1969, enacted by the Forty-first Session of the Legislative Assembly of the State of Montana, approved by Forrest H. Anderson, Governor of said State, on the twenty-fourth day of February, 1969, and effective on the twenty-fourth day of February, 1969.

IN TESTIMONY WHEREOF, I have hereunto set my hand and affixed the Great Seal of said State.

Done at the City of Helena, the Capitol of said State, this twenty-sixth day of February, 1969.

/s/ Frank Murray
Frank Murray
Secretary of State

. . . .

CHAPTER NO. 100
MONTANA SESSION LAWS 1969
SENATE BILL NO. 67

AN ACT PROVIDING FOR THE CONSERVATION AND DEVELOPMENT OF WATER AND LAND RESOURCES OF MONTANA THROUGH THE CREATION OF CONSERVANCY DISTRICTS.

BE IT ENACTED BY THE LEGISLATIVE ASSEMBLY OF THE STATE OF MONTANA:

Section 1. To provide for the conservation and development of the water and land resources of the state of Montana, conserve Montana's water for utilization for beneficial purposes within the state, and provide for the greatest beneficial use of water within this state, the organization of conservancy districts and the construction of works as defined by the act are a public use and will:

(1) be essentially for the public benefit and advantage of the people of Montana;

(2) benefit all industries of the state;

(3) encourage economic growth;

(4) indirectly benefit the state by increasing property valuations;

(5) directly benefit municipalities by providing adequate supplies of water for domestic uses;

(6) directly benefit lands irrigated or drained by works constructed;

(7) directly benefit lands now irrigated by stabilizing the flow of water in streams and by increasing the flow and return flow of water to those streams;

(8) enhance fish and wildlife habitat;

(9) improve recreational facilities; and

(10) promote the comfort, safety, and welfare of the people of Montana.

Section 2. The purpose of this act is to enable the formation of conservancy districts, comprised of area in one or more counties to promote the following purposes:

(1) prevent and control floods, erosion and sedimentation;

(2) provide for regulation of stream flows and lake levels;

(3) improve drainage and to reclaim wet or overflowed lands;

(4) promote recreation;

(5) develop and conserve water resources and related lands, forest, fish and wildlife resources;

(6) further provide for the conservation, development, and utilization of land and water for beneficial uses including, but not limited to, domestic water supply, fish, industrial water supply, irrigation, livestock water supply, municipal water supply, recreation, and wildlife.

Section 3. As used in this act, unless the context clearly indicates otherwise:

(1) "District" means a conservancy district, which is a public corporation and a political subdivision of the state.

(2) "Directors" means the board of directors of a conservancy district.

(3) "Elector" means a person qualified to vote under Section 23 of this act.

(4) Court'' means the district court of the judicial district in which the largest portion of the taxable valuation of real property of the proposed district is located and within the county in which the largest portion of the taxable valuation of real property of the proposed district is located within the judicial district.

(5) "Person" means a natural person; firm; partnership; cooperative; association; public or private corporation, including the state of Montana or the United States; foundation; state agency or institution; county; municipality; district or other political subdivision of the state; federal agency or bureau; or any other legal entity.

(6) "Water board" means the State Water Resources Board.

(7) "Board of supervisors" means the board of supervisors of the soil and water conservation district in which the largest portion of the taxable valuation of real property of the proposed district is located.

(8) "Works" means all property, rights, easements, franchises, and other facilities including, but not limited to, land, reservoirs, dams, canals, dikes, ditches, pumping units, mains, pipelines, waterworks systems, recreational facilities, facilities for fish and wildlife, and facilities to control and correct pollution.

(9) "Cost of works" means the cost of construction, acquisition, improvement, extension and development of works, including financing charges, interest and professional services.

(10) "Applicants" means any persons residing within the boundaries of the proposed district making a request for a study of the feasibility of forming a conservancy district.

(11) "Notice" means publication at least once each week for three (3) consecutive weeks in a newspaper published in each county, or if no newspaper is published in a county, a newspaper of general circulation in the county, or counties, in which a district is or will be located. The last published notice shall appear not less than five (5) days prior to any hearing or election held under this act.

(12) "Owners" are the person or persons who appear as owners of record of the legal title to real property according to the county records whether such title is held beneficially or in a fiduciary capacity, except that a person holding a title for purposes of security is not an owner nor shall he affect the previous title for purposes of this act.

(13) "Taxable valuation" shall mean the valuation determined according to Section 84-302, R.C.M., 1947, and does not mean assessed valuation.

Section 4. (1) To request a preliminary survey for a proposed conservancy district, the applicants shall present a written request to the water board.

(2) The request shall:

(a) generally describe the proposed boundaries of the district;

(b) specify the purpose or purposes of the district;

(c) list the works contemplated.

(3) The water board may initiate a preliminary survey without any prior request.

Section 5. (1) Sooner than eleven (11) days after the request is received, the water board shall acknowledge the request.

(2) The water board shall itself, or through cooperating agencies, or together with cooperating agencies:

(a) consult with the board of supervisors and all persons who may participate in the proposed project;

(b) conduct a preliminary survey of the proposed district;

(c) estimate costs of works, maintenance, and operation;

(d) determine sources of financing;

(e) reach a tentative decision on the feasibility, desirability and compatibility with the state water plan of the proposed district;

(f) adjust the boundaries of the proposed district to improve the feasibility, desirability or constency with the state water plan;

(g) sooner than six (6) months after receipt of the request, send a report of the preliminary survey to the applicants, the board of supervisors, fish and game commission, state soil conservation committee, state board of health, and other affected state and federal resource agencies for their comments.

Section 6. (1) Upon receipt of the preliminary survey report the applicants, or any one of them, may request the water board to hold a hearing. The water board shall hold the hearing sooner than sixty-one (61) days after receipt of the request. Notice of the hearing shall be given in accordance with Section 3, subsection (11) of this act.

(2) If the water board itself initiated the preliminary survey, it may hold such a hearing without being requested to do so.

Section 7. After the hearing, the applicants, or any one of them, may request the water board to prepare a detailed feasibility study of the proposed district. If the water board concludes that the proposed district is feasible, desirable, and consistent with the state water plan, it shall prepare a feasibility report, and sooner than six (6) months after receipt of the request, send copies to the applicants, if any, the fish and game commission, state soil conservation committee, state board of health, and other affected state and federal water resource agencies. For good cause shown based upon the actual technical problems in completing the report, the water board may use necessary additional time to complete and distribute the report. The detailed feasibility report shall describe the proposed works and contain an estimate of the cost of the works, the means of financing, and the estimated costs of operation and maintenance. The water board may adjust the boundaries of the proposed district to improve the feasibility, desirability and consistency with the state water plan, and to exclude land which would receive no direct or indirect benefits from the proposed district.

Section 8. If in the opinion of the water board the feasibility study shows that a district is feasible and consistent with the state water plan, the procedure for organization is:

(1) the water board shall file a petition requesting organization with the court;

(2) the petition shall:

(a) state the name of the proposed district;

(b) Give a legal description of the boundaries of the proposed district, excluding therefrom lands which would receive no direct or indirect benefits from the proposed district;

(c) describe the purposes of the district;

(d) describe the works;

(e) Indicate the estimated cost of works, means of financing, and estimated costs of operation and maintenance;

(f) list the taxable valuation of real property in the proposed district, which must be one hundred thousand dollars ($100,000) or more;

(g) describe the means of repaying capital costs;

(h) propose the persons who should be represented and the number of directors.

(3) The petition shall be signed by owners of at least fifty-one percent (51%) of the land outside the limits of an incorporated municipality, and not fewer than five percent (5%) or one hundred (100), whichever is the lesser, of the persons who would qualify as electors within an incorporated municipality.

Section 9. (1) Upon receipt of a petition for organizing a district, the court shall give notice and hold a hearing on the petition. If the courts shall find that the prayer of the petition should be granted, it shall:

(a) make and file findings of fact specifying those lands that will be directly or indirectly benefitted by the proposed district, and exclude those lands which will not be so benefitted;

(b) make an order fixing the time and place of an organizing election;

(c) give notice of an election in the way provided in Section 3, subsection (11);

(d) provide for election judges and fix their compensation;

(e) fix the polling place or places as necessary;

(f) order the county clerk to provide poll books, ballots, poll lists and other necessary election supplies;

(g) provide for canvassing the results;

(h) declare the results;

(i) order and decree the district organized if the requisite number of eligible electors vote in favor of organization.

(2) In order for the district to be organized, fifty-one percent (51%) or more of the eligible electors must vote in the election, and a majority of those voting must vote in favor of organization.

(3) This act shall not confer upon the court jurisdiction to hear, adjudicate, and settle questions concerning the priority of appropriation of water between districts and other persons. Jurisdiction to hear and determine priority of appropriation, and questions of right growing out of, or in any way connected with a priority of appropriation, are expressly excluded from this act and shall be determined as otherwise provided by the laws of Montana.

Section 10. Sooner than thirty-one (31) days after the district has been decreed organized, the clerk of the court shall transmit to the secretary of state, water board, and to the county clerk and recorder in each of the counties having lands in the district, copies of the election results, the decree of the court incorporating the district, and a description of the boundaries of the district. Copies of the same documents shall be filed in the office of the secretary of state in the same manner as articles of incorporation are required to be filed under the laws governing corporations. Copies shall also be filed in the office of the county clerk and recorder of each county in which a part of the district may be. The clerk and recorder of each county where the articles are filed and the secretary of state shall collect filing fees as provided by law.

Section 11. If organized, the district shall reimburse the county, or counties, for the expenses incurred in the organizing election.

Section 12. If a district is organized, the court shall:

(1) establish by court order the number of persons who shall comprise the directors, appoint persons who are electors within the district to membership on the board of directors, and fix their compensation. The number shall not be less than three (3) nor more than eleven (11) persons. In fixing the number and making the appointments the court shall consider the interests and purposes to be served by the district. Upon a verified petition filed by a majority of the directors and for good cause shown, the court may enlarge or reduce the membership of the directors, but not to exceed eleven (11) nor to be less than three (3);

(2) fix the terms of office so that approximately one-third (1/3) of the directors first appointed shall serve for one (1) year; approximately one-third (1/3) shall serve two (2) years; and the remainder shall serve three (3) years. All succeeding terms shall be three (3) years. Unless excused for good cause, a director who misses three (3) consecutive regular meetings has vacated his position;

(3) fill all vacancies on the board by appointment or reappointment;

(4) specify a date for the first annual meeting of the directors;

(5) specify the amount and form of a corporate surety bond which each member of the directors shall furnish at the expense of the district, conditioned upon his faithful performance of his duties as a director.

Section 13. (1) The directors shall select from among themselves a chairman, vice-chairman, secretary, and other necessary officers. The directors shall adopt bylaws and rules for the conduct of meetings. All official acts of the directors shall be entered in a book of minutes to be kept by the secretary.

(2) The directors shall establish times for regular meetings and may hold special meetings upon the call of the chairman or any two (2) members, and (except in case of emergency) upon at least three (3) days notice of the time, place, and purpose of the meeting.

Section 14. On behalf of the district, the directors may:

(1) adopt an official seal;

(2) sue and be sued;

(3) adopt rules to promote and encourage water recreation, including requirements concerning public access areas and facilities, and rules respecting the use of reservoirs and waters, picnic sites, and other recreational areas operated by the district. Rules adopted shall be filed with the secretary of directors and shall be available to any interested party upon reasonable request;

(4) enter private property for the purposes of making surveys, provided that just compensation for actual damages is made;

(5) provide for reimbursing of its members for actual expenses;

(6) appropriate water and initiate or participate in the adjudication of streams;

(7) acquire, undertake, construct, develop, improve, maintain, and operate works and all incidental facilities;

(8) acquire by purchase, exchange, gift, lease, grant, devise, or otherwise, lands, water, water rights, or rights-of-way as necessary for the execution of any authorized function of the district. Title to all property (including water rights) shall be in the name of the district;

(9) merge with other special districts as hereinafter provided;

(10) hold and dispose of property as necessary or convenient in the performance of the functions of the district;

(11) call upon the county attorney or attorney general for such legal services as the district may require, or in the discretion of the directors, employ private legal counsel;

(12) withhold the delivery of water upon which there are any defaults or delinquencies of payment, and otherwise dispose of that water while the default or delinquency continues;

(13) borrow money and incur indebtedness and issue bonds to finance works as provided by this act;

(14) refund bonded indebtedness incurred by the district as provided by this act;

(15) after a hearing held in accordance with Section 17 of this act, make assessments sufficient to meet the budgetary requirements for the coming year;

(16) contract for service, for water furnished, or for the sale of water with any person;

(17) fix and revise from time to time and collect rates, fees, and other charges for the services, facilities, or water furnished by the district to any person;

(18) allocate or reallocate unused waters of the district;

(19) cooperate with; accept grants, loans, and other assistance from; act as agent for; and enter into agreements with any and all state or federal agencies, and exercise all necessary or convenient powers in connection therewith;

(20) enter into any obligation or contract with an agency of the federal government for the construction, operation, and maintenance of works; or for the assumption as principal or guarantor of indebtedness to the United States on account of district lands under the provisions of the federal reclamation act and rules established under that act; or contract with an agency of the federal government for a water supply under any federal act providing for or permitting such a contract. However, the action must be approved by a majority of the electors voting at an election held as provided in Section 24. If a contract is made with an agency of the federal government, the directors may deposit bonds of the district with the United States at ninety percent (90%) of their par value, to secure the amount to be paid by the district to the United States under any contract, the interest on the bonds of the district to be applied as specified by the contract. If bonds of the district are deposited with the United States, it is the duty of the directors to make an assessment sufficient to meet all payments accruing under the terms of any contract with the United States;

(21) accept appointment of the district as fiscal agent for the United States or authorization of the district to make collections of moneys for or on behalf of the United States in connection with any federal reclamation projects and the district is authorized to act and to assume the duties and liabilities incident to this action. However, the action must be approved by a majority of the electors voting at an election held as provided in Section 24. The directors may do all things required by federal statutes and rules and require prompt payment of all charges as a prerequisite to water service;

(22) in addition to all voted indebtedness, borrow money as necessary but the amount shall not at any one time exceed five percent (5%) of the taxable valuation of real property in the district;

(23) mortgage property owned by the district if the terms of the mortgage are not inconsistent with the provisions of a resolution authorizing the sale of bonds;

(24) use any surplus funds to purchase outstanding bonds;

(25) make contracts incidental to the performance of the district's functions, and employ and fix the compensation of employees, agents or consultants as are deemed necessary, including but not limited to, a manager, attorneys, accountants, engineers, construction and financial experts;

(26) cooperate with soil and water conservation districts to obtain agreements to carry out soil conservation measures and proper farm plans from owners of lands situated in the drainage area above each retention reservoir to be installed with federal assistance.

Section 15. A district organized under this act, by itself or in conjunction with others, as a sponsoring organization to participate in all federal programs including, but not limited to, the Watershed Protection and Flood Prevention Act of 1954 (68 Stat. 666), the Federal Water Project Recreation Act of 1965 (79 Stat. 213), the Federal Recalamation Act of 1902 (32 Stat. 388), and amendments to those acts.

Section 16. (1) To the extent that anticipated revenues from rates, fees, and other charges fixed pursuant to Section 14, subsection (17) will not be sufficient to meet the district's anticipated obligations for annual operation, maintenance, and replacement or depreciation of works, or for payment of the interest and principal on bonded indebtedness, the directors may make an assessment of not more than two (2) mills on all taxable real property in the district for the purpose of fully meeting such obligations.

(2) In addition to the assessment authorized by subsection (1), the directors may annually make an assessment of up to three (3) mills on the taxable real property in the district to pay interest and principal on bonded indebtedness.

(3) The assessments are a lien upon each lot or parcel of land within the district to the extent of the assessment on each.

(4) All assessments have the same force and effect as other liens for taxes and their collection shall be enforced in the way provided for enforcement of liens for county taxes. Assessments, if not paid, become delinquent at the same time as county taxes.

(5) Except as provided in Section 29, approval of the electors is not required for the making of these assessments.

Section 17. (1) The directors shall, prior to the first Monday in May of each year, give notice as provided in Section 3, subsection (11) of this act of the intention to hold a public budget hearing. The notice shall include the date, time, place, and general agenda.

(2) At the hearing, the directors shall:

(a) review the present budget;

(b) present the budget for the next year;

(c) hear and consider protests from any elector;

(d) adopt the budget for the next year;

(e) set the assessment for the next year.

Section 18. (1) Before the second Monday in July of each year, the directors shall provide the county assessor and treasurer with:

(a) the budget for the current fiscal year;

(b) a statement of the amount of special assessments to be collected for the districts;

(c) a listing of all real property within the district.

(2) If the district is located in more than one (1) county, the directors shall provide this information to each of the county assessors and treasurers.

Section 19. (1) The treasurer of each county in which the district is located shall collect special assessments at the same time and in the same way as county taxes.

(2) If the district is located in more than one (1) county, all assessments collected shall be deposited with the treasurer of the county in which the assessments were collected.

(3) The directors shall direct the county treasurer to invest any surplus district funds in saving or time deposits in a state or national bankinsured by the Federal Deposit Insurance Corporation or in direct obligations of the United States government payable within one hundred eighty (180) days from the time of investment. All interest collected on the deposits or investments shall be credited to the fund from which the money was withdrawn. However, five percent (5%) of the interest shall be deposited in the general fund of the county.

Section 20. The district may exercise the right of eminent domain in the manner provided by the law to take private property for public use, with just compensation, where the taking is necessary for the purposes of the district. Water rights as such shall not be subject to such taking, but may be taken as an incident to the condemnation of land to which such rights are appurtenant, where the taking of the land is the principal purpose of the condemnation.

Section 21. Before August 1 of each year, the directors shall send a written report of their activities during the previous fiscal year to the court and to the water board. Reports shall be in the form, and contain the information, prescribed by the water board.

Section 22. At least once each year the state examiner shall examine the financial records of each district and file a report of the examination with the water board and court. The state examiner shall collect a fee for the examination equal to that charged irrigation districts.

Section 23. (1) Only persons who are taxpayers upon and owners of real property located within the district and whose names appear upon the last completed assessment roll of some county within the district for state, county and school district taxes are electors and shall be entitled to vote in elections, provided that:

(a) an elector need not reside within the district in order to vote;

(b) where a corporation owns taxable real property within the boundaries of the conservancy district, the authorized agent of such corporation shall be entitled to cast a vote on behalf of the corporation;

(c) where land is under contract of sale to a purchaser and the contract is recorded, only the purchaser shall have the right to vote;

(d) guardians, executors, administrators, and trustees of real property within the district, shall be entitled to cast the vote for the Owner of the land.

(2) When voting, an agent of a corporation (sic) or of co-owners, or a guardian, executor, administrator, trustee, or purchaser under contract of sale, may be required to show his authority by the judges of the election.

Section 24. Election procedures after organization are:

(1) The directors shall designate the polling places, at least one (1) in each county, and hours when the polls will be open;

(2) Notice shall be published of the location of polling places and hours when the polls are open as provided in Section 3, subsection (11) of this act;

(3) The directors shall appoint three (3) judges for each polling place and fix their compensation;

(4) The judges shall appoint one (1) of their number as clerk of the election;

(5) The clerks and recorders of the counties in which the election is to be held shall supply poll lists, registers, ballots, and other necessary election supplies;

(6) The judges shall cause the ballots to be counted and certify the results to the directors;

(7) The directors shall canvass the returns;

(8) The directors shall reimburse the counties for actual expenses incurred in the election.

Section 25. An elector may challenge any person who claims the right to vote. Before voting, any person challenged must take and sign the following oath or affirmation administered by an election judge:

"I. . . . . . (name). . . . . . solemnly swear (or affirm) that I am an elector of the district and have not voted today." False subscription to the oath or affirmation is perjury and punishable as such.

Section 26. A district may issue bonds payable from revenues, assessments, or both, or the district may use other financing as provided by this act for the cost of works. Bonds issued shall be for a maximum term of not to exceed forty (40) years and a maximum rate of interest not more than six percent (6%). Bonds for more than one purpose may be sold as a single issue.

Section 27. In determining the amount of bonds to be issued, the directors may include:

(1) All costs of works;

(2) All costs and estimated costs of issuance of the bonds;

(3) interest which they estimate will accrue on money borrowed during the construction period and for six (6) months after the period.

Section 28. When the directors find it necessary to issue bonds, the directors shall:

(1) pass a resolution which includes:

(a) the purpose or purposes for which the bonds will be issued;

(b) the maximum amount and term of the bonds;

(c) the maximum interest rate the bonds will bear;

(d) whether the bonds will be repaid from revenues, assessments, or both.

(2) give notice as provided in Section 3, subsection (11) of this act which shall include the resolution adopted by the directors, location of polling places, and hours when the polls will be open;

(3) hold an election as provided by Section 24 of this act.

Section 29. (1) For a bond issue to be approved, forty percent (40%) of the qualified electors must vote thereon, and sixty percent (60%) of those voting must approve the issue.

(2) Approval of the bond issue shall authorize the directors to make assessments as provided in Section 16 necessary to pay the principal and interest on bonds issued.

(3) The directors shall enter the results of the election in their records.

(4) If otherwise fairly conducted, no irregularities or informalities shall invalidate the election.

(5) Bonds for more than one purpose may be submitted to the electors as a single proposition.

Section 30. If a bond issue is approved, the directors shall by resolution provide for the form and execution of the bonds and for issuance of all or any part of the bonds. After adequate notice that sealed proposals will be received, the directors may award the purchase of all or a part of the issue to the best bidder or bidders, and may sell at private sale any or all bonds not sold on bids.

The said bonds will be sold for not less than their par value with accrued interest to date of delivery, and all bidders must state the lowest rate of interest at which they will purchase the bonds at par. The board shall reserve the right to reject any and all bids and to sell the said bonds at private sale.

Section 31. Bonds issued under this act have the same force, value, and use as bonds issued by a municipality and are exempt from taxation as property within the state of Montana.

Section 32. Pending preparation of the bonds sold under this act, receipts or certificates may be issued to purchasers in the form, and with provisions, as determined by the directors. Bonds and interim receipts or certificates are fully negotiable as provided by the Uniform Commercial Code-Investment Securities.

Section 33. (1) When duly executed, all bonds issued under this act shall be registered by the county treasurer of the county in which the largest portion of the taxable valuation of real property of the district is located. They shall be registered in a book provided for that purpose before being delivered to the purchaser.

(2) The registration shall show:

(a) The number and amount of each bond;

(b) the date of issue and date redeemable;

(c) the name of the purchaser;

(d) the amount and due date of all payments required on the bonds.

(3) The directors shall provide the county treasurer with an unsigned and cancelled printed copy of each issue of bonds of the district. The copy shall be preserved in his office.

Section 34. (1) Proceeds from the sales of bonds shall be deposited with the county in which the largest portion of the taxable valuation of real property of the district is located.

(2) The county treasurer shall place the proceeds of the bond sale to the credit of the district. The proceeds shall be paid by the county treasurer on written order of the directors. Proceeds shall only be spent for the purposes for which the bonds were issued.

(3) The directors shall instruct the county treasurer to deposit any part of the proceeds which is not immediately needed for the purpose for which the bonds were issued in a saving or time deposit in a state or national bank insured by the Federal Deposit Insurance Corporation or to invest in direct obligations of the United States government. The obligations shall be payable within not to exceed one hundred eighty (180) days from the time of deposit or investment.

Section 35. (1) Refunding bonds may be issued in the same way as any other bonds authorized by this act.

(2) All bonds, original issue or refunding issue, shall be redeemable when one-half (1/2) of the terms or ten (10) years of the term for which they were issued, whichever may be the less, has expired. Redemption may be made on any interest due date of any bond prior to its maturity after the bond shall be subject to redemption as herein provided. The right of redemption, as herein provided, must be stated on the face of each bond.

Section 36. Revenue, assessment, and other funds on hand, including reserves pledge for the payment and security of outstanding bonds may be deposited in a fund created for the retirement of bonds and may be invested and disbursed as provided by this act, to the extent consistent with the resolution authorizing the outstanding bonds.

Section 37. (1) The directors by resolution may establish revolving funds to finance, on a reimbursable basis:

(a) construction, purchase, lease and operation of revenue producing works;

(b) contracts to provide services or facilities.

(2) Money in the revolving fund shall not be spent for any purposes other than those specified in the resolution. However, excess money may be transferred to any sinking and interest fund of the district.

(3) The county treasurer of the county having the largest portion of the taxable valuation of real property of the district shall maintain a separate account for each revolving fund of the district, and all money collected under the resolution shall be deposited with the county treasurer.

Section 38. (1) In case two (2) or more districts have been organized in a territory which, in the opinion of the directors of each of the districts, should constitute but one (1) district, the directors of the districts may petition the court for an order merging the districts into a single district. The petition shall be filed in the office of the clerk of the district court in and for that county which

has the largest portion of taxable valuation of property within the districts sought to be included, as shown by the tax rolls of the respective counties. The petition shall set forth facts showing that the purposes of this act would be served by the merging of the districts, and that the merger would promote the economical execution of the purposes for which the districts were organized. A copy of the petition shall be filed with the water board.

(2) Upon the filing of the petition, the court shall by order fix a time and place of hearing; and the clerk shall give notice as specified in Section 3, subsection (11) of this act as well as by mail to the directors of the districts which would be merged. The notice shall contain the purpose, time, and the place of the hearing.

(3) Upon the hearing, should the court find that the averments of the petition are true and that the districts, or any of them, could feasibly and profitably be merged, it shall order that the merger take place and the districts shall be merged into one (1) district and proceed as such. The court shall designate the corporate name of the district, and further proceedings shall be taken as provided for in this act. The court shall by order appoint the directors of the district, who shall thereafter have powers and be subject to rules as are provided for directors in districts created in the first instance.

(4) Instead of organizing a new district from the constituent districts, the court may, in its discretion, direct that one (1) or more of the districts described in the petition be included in another of the districts, which other shall continue under its original corporate name and organization; or the court may direct that the district or districts so absorbed shall be represented on the directors of the original districts, designating what members of the directors of the original district shall be retired from the new board, and what members representing the included district or districts shall take their places.

(5) If the court receives a petition opposing the merger, signed by a majority of the electors of any of the concerned districts, the court shall not grant the order and shall dismiss the petition.

(6) Upon merger or inclusion, existing obligations shall remain exclusively with those who bore them prior to the merger or inclusion, except with the written consent, given prior to the merger or inclusion, of those who did not bear the obligations.

Section 39. To annex real property to the district, the procedure is:

(1) The directors shall petition the court.

(2) The petition shall:

(a) Give a general description of the real property to be annexed sufficient to enable a person to determine if his property is in the proposed annexation;

(b) describe the benefits to accrue to the real property as a result of the annexation;

(3) The court shall:

(a) give notice and hold a hearing on the petition;

(b) upon good cause shown, order or deny the annexation.

Section 40. Real property annexed to a district shall not incur any liens by reason of bonds issued before annexation unless agreed to by the owners of the annexed property, in writing, prior to annexation.

Section 41. Any territory included within any district formed under the provisions of this act, and not benefited in any manner by such district, or its inclusion therein, may be excluded therefrom.

The procedure for exclusion is:

(1) A petition for exclusion shall be initiated by either the directors or the owner or owners of the land sought to be excluded.

(2) The petition shall give a description of the territory sought to be excluded sufficient to enable a person to determine if his property is in the proposed exclusion and shall set forth that such territory is not benefited in any manner by the district or its continued inclusion therein, and shall request that such territory be excluded from the district.

(3) When owners of property initiate the petition for exclusion, the petition shall be filed with the secretary of the district and shall be accompanied by a deposit of one hundred dollars ($100) to meet the costs incident to the process of exclusion. The unexpended balance of the deposit shall be returned to the petitioner.

(4) Upon the filing of such petition with the secretary of the district, the secretary shall duly call a meeting of the directors to consider the petition. The directors shall approve or disapprove of the merits of the petition. The secretary shall then file the petition, together with a copy of the action of the directors, with the court.

(5) The court shall give notice, hold a hearing, and issue an order either granting or denying the petition.

Section 42. (1) The procedure for dissolution of a district is:

(a) A resolution shall be passed by the directors requesting dissolution; or

(b) a petition signed by twenty percent (20%) of the electors representing ten percent (10%) of the taxable valuation of real property in the district shall be presented to the directors; or

(c) if the district or its directors have been inactive for one (1) year or more, any elector may present a petition.

(2) The resolution or petition shall be presented to the court by the directors, or by the petitioners if the directors remain inactive.

(3) Not more than one (1) resolution or petition may be presented to the court in any twenty-four (24) month period, and no such petition may be presented during the first twenty-four (24) months after a district's initial organization.

Section 43. (1) After receipt of petition or resolution for dissolution, the court shall order an election in the way provided by Section 24 of this act.

(2) For dissolution to be approved, a majority of the electors voting must favor dissolution.

Section 44. (1) In the event the vote is for dissolution, any qualified elector, or the board of directors of the district may, within the time fixed by the court, present a written plan for terminating the affairs of the district which shall include assignment of any water rights and works owned by the district.

(2) The plan may specify that the affairs of the district shall be terminated by the directors or by a receiver appointed by the court.

(3) On a day fixed by the court, the court shall consider the plan or plans and shall enter an order establishing a plan for the termination of the affairs.

(4) The court shall retain jurisdiction to modify the plan and shall supervise the termination.

Section 45. (1) If no plan is presented on or before the date set by the court, the court shall appoint a receiver to terminate the affairs of the district under the supervision of the court.

(2) Upon the appointment of any receiver all the authority of the directors shall cease. However, until dissolution, the receiver shall have authority to levy assessments for:

(a) the payment of obligations of the district;

(b) the costs of termination.

(3) The directors, or if there is a receiver, then the receiver with the approval of the court, shall make assessments each year in an amount large enough to retire the obligations of the district.

(4) If a receiver has been appointed, he shall direct, under court supervision, the disposition of all assessments collected.

Section 46. When it appears to the satisfaction of the court that:

(1) all obligations of the district have been discharged;

(2) all the costs of termination have been paid, the court shall enter an order dissolving the district. A certified copy of the order shall be recorded by the clerk of the court in all counties in which the district was situated and filed with the secretary of state.

Section 47. All funds remaining after dissolution of a district shall be deposited in the general fund of the counties in which the district is located in proportion to the taxable value of property within the district in each county.

Section 48. No power to generate, distribute or sell electric energy.

Nothing in this act shall be construed to grant to the district the power to generate, distribute or sell electric energy.

Section 49. The provisions of this act shall not be construed to, in any manner, abrogate or limit the rights, powers, duties and functions of the water board, state soil conservation committee, soil and water conservation districts, state board of health, or the fish and game commission; but shall be held to be supplementary thereto and in aid thereof.

Section 50. It is the intent of the legislative assembly that if a part of this act is invalid, all valid parts that are severable from the invalid part remain in effect. If a part of this act is invalid in one or more of its applications, the part remains in effect in all valid applications that are severable from the invalid applications.

Section 51. This act shall be effective immediately upon passage and approval.

SENATE BILL NO. 67

APPENDIX E

MWRB LAND CLASSIFICATION CRITERIA

RECONNAISSANCE LAND CLASSIFICATION SPECIFICATIONS
MISSOURI BASIN REGION, MONTANA
STATE WATER PLAN
MONTANA WATER RESOURCES BOARD - LAND CLASSIFICATION SECTION

Soil or Land Characteristics	Class 1* Only Slight Limitations	Class 2* Moderate Limitations	Class 3 Severe Limitations
Dominant texture of Root Zone	Fine sandy loam to friable clay loam	Loamy sand to permeable clay	Loamy sand to clay (sands with sufficient w.h.c. can be included.)
Depth to: Clean sand, gravel and cobble	40" minimum	20" minimum	10" minimum
(A) Hard rock, Sandstone or non-saline Shale	60" minimum	40" minimum	30" minimum
Textural Modifiers **Vol. of Coarse Fragments in Tillage Layer** Gravel (<3") Cobble (3-10")	No problem in tillage <15%	Moderate problem in tillage 15 to 50% <3" <15% (3-10")	Severe problem in tillage >-50% <3" 15 to 50% 3-10"
(B) Stoniness of surface and tillage layer, stones generally greater than 12" in diameter.	No problem in tillage	Cultivation not impractical. Stones >12" diameter; occupy 0.01 to 0.1% of the surface, and 0.15 to 1.5 cubic yards per acre foot.	Cultivation impractical unless cleared. Stones >12" diameter; occupy 0.1 to 3% of the surface, and 1.5 to 50 cubic yards per acre foot.
(B) Rockiness (Small outcrops within Soil type)	No problem in tillage Less than 2% of bedrock exposed.	=2% of surface may have bedrock exposed	2 to 10% surface may have bedrock exposed

In areas where use has demonstrated suitability, more severe modifiers can be rated irrigable for special uses not requiring tillage.

Soil or Land Characteristics	Class 1* Only Slight Limitations	Class 2* Moderate Limitations	Class 3 Severe Limitations
Available water-holding capacity (to a maximum depth of 4 feet)	> 6"	>4"	> 2"
Permeability	Moderately slow - .20 inches per hour to moderate - 2.00 inches per hour, may exceed 2 inches per hour if sufficient water holding capacity is maintained - by field observation of soil texture, structure, etc.	Slow - .06 inches per hour to moderately rapid - 2.00 to 6.30 inches per hour - by field observation of soil texture, structure, etc.	Very slow - less than .06 inches per hour only in thin layers. To rapid - greater than 6.30 inches per hour if upper 4 feet of soil has sufficient water holding capacity - by field observation of soil texture, structure, etc.
Salinity and/or Alkalinity	Electrical conductivity not to exceed 4 millimhos/cm. may be higher under good leaching and drainage conditions. But not to exceed 8 millimhos/cm in top 4 ft.	Electrical conductivity not to exceed 8 millimhos/cm; except under good leaching and drainage conditions. Most horizons will have less than 8 millimhos/cm.	Electrical conductivity not to exceed 8 millimhos/cm in top 2 feet. Lower horizons may be higher under good leaching and drainage conditions, but not to exceed 15 millimhos/cm.

Slight or moderate salinity or alkalinity may exclude soils from Classes 1 through 3 if associated with either or both a slow permeable substrata, or saline shale. Exchangeable sodium greater than 3.0 millequivalents per 100 grams and/or sodium adsorption ratio greater than 12 of soil for cation exchange capacities less than 25 millequivalents per 100 grams - may exclude a soil from irrigable class if leaching is not practical.

Soil or Land Characteristics	Class 1* Only Slight Limitations	Class 2* Moderate Limitations	Class 3 Severe Limitations
	Topography		
Slope	0-4%	<8%	15% (Sprinkler irrigation on slopes >8%)
	Drainage		
(C) Water Table	Easily maintained below 5' depth during growing season.	Practical to maintain below 40" depth most of the time in growing season (requires drainage)	Can maintain below 20" most of the growing season.
Overflow	No overflow	Free of overflow in growing season	Overflow may be hazard to crops in some years (2 or 3 in 10)
	Climate		
	Growing season greater than 90 days.	Growing season greater than 90 days.	Growing season may be less than 90 days.

Footnotes:
* Any one deficiency below the limits of a class is cause for downgrading to next lower class. Two or more such deficiencies may cause downgrading two classes if judgement indicates they are additive in effect. Combinations of less severe deficiencies will be evaluated on a judgement basis.

(A) Soils known to be underlain by saline shale at depths as shallow as 60 inches are excluded from Class 1 through 3.

(B) For detailed description see Soil Survey Manual U.S.D.A. pp 217 & 220.

(C) Applicable only if soils in Classes 1 through 3 are permeable enough to permit leaching of salts when drainage is provided.

The basic assumptions that are being proposed for consideration in the land classification study are:

1. Assume that all future development will be sprinkler irrigation or surface methods with an efficiency equivalent to sprinklers.
2. Irrigable land classes can be lowered due to climate, but not entirely eliminated; mountain-meadows are being irrigated for hay production and should be considered as Class 3 land.
3. The exclusion of acreages due to future development of canals, roads and other right-of-way development within an arable area will amount to a six percent reduction.
4. The exclusion of acreages near expanding towns, cities and suburban areas will vary according to local conditions.
5. The land classification will be a basic general reconnaissance inventory to determine the suitability of land for future irrigated agriculture regardless of the water supply.
6. The given land class of any area will be the dominant class and areas containing less than 100 acres of a higher or lower land class may be present within a delineated boundary line. The office map size will be 1: 125,000. Map size for reports will be less than 1: 125,000 and the minimum acreage size will be greater than 100 acres in size.
7. The reconnaissance land classification is general and broad assumptions may be necessary in areas where little soil information is available; the survey should not be considered adequate for a detailed project plan. Large areas of detail soil surveys will be shown on the maps, however, the areas where broad assumptions are made will not show small areas of soil surveys.
8. The Land Classification Standards are considered as a guide and local conditions will sometimes vary from them.

APPENDIX F

CROP YIELDS AND AGRICULTURAL ECONOMICS DATA

TAP INC

ECONOMIC CONSULTANTS

P.O. Box 471 25 East Mendenhall, Bozeman, Montana 59715 Ph. Area 406 587 4461

July 21, 1970

MEMO

TO: Robert D. Catton, P.E.
Henningson, Durham & Richardson, Inc.
3555 Farnam Street
Omaha, Nebraska 68131

FROM: Lloyd C. Rixe, President
T.A.P., Inc.
Box 471
Bozeman, MT 59715

RE: Cost, Yields & Prices Associated with Dryland & Potentially Irrigated Crops in the North Central Study Area

Attached to this memo you will find a table outlining or estimating the typical kinds of costs associated with the growing of each crop with also a notation of the approximate yields and prices associated with these crops. I am sure that you reoognize that defining typical situations in terms of costs and yields is difficult because there is such a tremendous variance depending upon many factors associated with the individual farm and ranch situation. They depend upon managerial abilities and practices, size of farm, independet of management effort and a whole host of related factors. To the best of our ability these are costs that can be used as "ball park" estimates and should be viewed as estimates and not for planning purposes on individual units, or for that matter to be used as criteria for determining an optimum crop to be grown and so forth.

Most of the material contained in these tables is based directly upon publications of the Montana Cooperative Extension Service published through Montana State University.

We have made judgments and adjustments in this material in certain instances and in other instances, the costs are nearly the same as those published by the Extension Service. We have also spent some time visiting with the Production Economics people within the Extension Service to double-check some of our thinking regarding these costs estimates. We want to certainly caution you that these estimates are

to be viewed as estimates and that one would expect a considerable amount of variance to exist in farm to farm situations. The estimates are constructed to the best of our ability to represent an average or typical situation.

The costs which we have estimated for each crop consist of the direct operating costs plus five percent of the direct operating cost classified as miscellaneous overhead costs. The management cost has been priced at ten percent of the direct operating and miscellaneous overhead costs. This total was then recorded, and an interest on the operating capital was figured on five percent of the direct operating costs, miscellaneous overhead costs and management costs.

The reason for using the five percent interest rate for operating capital was that the operating capital on most costs tends to be tied up for only part of the year. Therefore, five percent or half of the effective rate was used as interest on operating capital.

The total cost for each crop then consists of the four items of direct operating cost, miscellaneous overhead cost, management cost and interest on operating capital. It should be pointed out that none of the cost estimates for individual crops contained any costs associated with real estate for either land or buildings. In other words there is no cost assigned to the individual crops for interest on investment in real estate or associated irrigation systems and water costs.

The normal items associated with real estate costs would be depreciation, interest, taxes, water and insurance. These items have not, however, been included in the cost estimates herein. It would probably be possible to make a gross estimation of real estate costs as associated with irrigated land and dryland and add that amount on to the cost as contained here to estimate total costs. This must be done consistent with land values and water costs, which I am sure from visiting with you, are worked out separately and independent from crop costs per acre.

Certain published data would give you such a ball park percentage which could be applied to irrigated land and dryland if you require this in your system. It is my understanding that you wanted the costs in terms of direct operating costs.

Lloyd C. Rixe

Lloyd C. Rixe
President

IRRIGATED PASTURE*

Direct Operating Costs:

Harrow	1.20
Irrigate (7)	4.04
Clip (3)	1.78
Fertilizer (2)	16.00
Annual Cost of Stand Establishment	3.00
1. Sub-total	$26.02
2. Miscellaneous Overhead (Five percent of line 1)	1.30
3. Total Operations	$27.32
4. Management (Ten percent of line 3)	2.73
5. Total Operations & Management	$30.05
Interest on Operating Capital	1.50
TOTAL	$31.55

YIELD: 8 to 12 A.U.M.'s per acre

PRICE: $3.50 to $4.50 per A.U.M.

* The costs associated with irrigated pastures are primarily based upon material found in Bulletin 1069 of the Montana Cooperative Extension Service. Irrigated pasture is an extremely hard thing to price in that irrigated pastures A.U.M.'s are not commonly sold in the market place but rather grazed by livestock on the farm. The best indication of their value would be the price paid by the livestock operators in purchasing A.U.M.'s needed to supply their operation. This price varies from $3.50 to $4.50 per A.U.M., and therefore I would say that this is a representative value to be associated with A.U.M.'s of irrigated forage.

The yield estimate of 8 to 12 A.U.M.'s per acre indeed shows fantastic variation. This point is clearly illustrated by Bulletin 1057 published by the Montana Cooperative Extension Service in 1968, which works out an annual irrigated pasture costs assuming less than two A.U.M.'s per acre in the Fairfield, Montana, area while a similar publication, Bulletin 1069, shows an irrigated pasture yield of 12 A.U.M.'s with very little difference in cost for the south central Montana area. Yields of irrigated pastures do vary all the way from 1 to 2 per acre to as much as 15 to 20 in the most intensive operations. The yield assumed is 8 to 12, but a 6 to 12 would also be a sound assumption even though it is an extremely large range.

DRY LAND WINTER WHEAT*

Direct Operating Costs:		
	Chisel - fall	.74
	Offset Disc	.97
	Duckfoot	.74
	Rodweeder	.47
	Drill	5.24
	Weed Spray	.48
	Combine	3.20
	Two ton truck	1.71
	Two ton truck	.83
	Auger	.15
	Pickup	.68
	Service Truck	.31
	Hail Insurance	2.80
1.	Sub-Total	$18.32
2.	Miscellaneous Overhead Five percent of line 1	.92
3.	Total Cost of Operations	$19.24
4.	Management (Ten percent of line 3)	1.92
5.	Total Operations & Management	$21.16
	Interest on Operating Capital	1.06
	TOTAL	$22.22

* Major reference Bulletin 1060 of the Montana Cooperative Extension Service

DRY LAND ALFALFA*

Direct Operating Costs:

Swather (1)	2.99
Baler (1)	5.74
Stack (1)	1.47
Pickup	1.33
1. Sub-total	$11.53
2. Miscellaneous Overhead (Five percent of line 1)	.58
3. Total Operations	$12.11
4. Management (Ten percent of line 3)	1.21
5. Total Operations & Management	$13.32
Interest on Operating Capital	.66
TOTAL	$13.98

* Major reference Bulletin 1069 of the Montana Cooperative Extension Service The total for irrigated alfalfa hay of three tons per acre was divided in half and then multiplied by .8 to estimate one ton-one cutting on dryland.

DRY LAND
OATS, SPRING WHEAT & BARLEY*

COSTS:

Chisel - spring	.74
Duckfoot	.74
Duckfoot - rod	.74
Duckfoot - rod	.74
Drill	4.20
Weed Spray	.47
Combine	4.00
Two ton truck	1.71
Two ton truck	.83
Auger	.15
Pickup	.68
Service Truck	.31
Hail Insurance	1.70
1. Sub-Total	$17.01
2. Miscellaneous Overhead Five percent of line 1	.85
3. Total Cost of Operations	$17.86
4. Management (Ten percent of line 3)	1.79
5. Total Operations & Management	$19.65
Interest on Operating Capital	.98
TOTAL	$20.63

* Based on Great Falls, Major reference Bulletin 1060 of the Montana Cooperative Extension Service.

ALFALFA HAY IRRIGATED*

Direct Operating Costs:

Establishment Cost (est. total $25 per acre or $5 per year for 5 years)	5.00
Fertilization	5.85
Ditching & Irrigation (3)	3.00
Swatcher (2)	7.48
Baler (2)	14.34
Stack (2)	3.68
Pickup	3.33
1. Sub-Total	$42.68
2. Miscellaneous Overhead (Five percent of line 1)	2.13
3. Total Operations	$44.81
4. Management (Ten percent of line 3)	4.48
5. Total Operations & Management	$49.29
Interest on operating capital	2.46
TOTAL	$51.75

PRICE: $20 to $30 per 25 acres

YIELD: 3 tons per acre estimated

* The alfalfa hay costs are based primarily upon Bulletin 1056 of the Montana Cooperative Extension Service and also Bulletin 1069. The establishment costs was assumed to be approximately $25.00 per acre, and therefore a $5 per year establishment cost was included as an annual cost of alfalfa hay on irrigated property.

IRRIGATED BARLEY*

Direct Operating Costs:

Plow	4.74
Disc	1.50
Level (2)	3.14
Dick with level	3.13
Drill	4.94
Irrigate (2)	2.00
Spray	1.30
Swath	3.00
Combine	6.50
Bale (Straw)	4.68
Stack	3.00
Trucking	4.50
Insurance (Hail)	2.50
Pickup	2.00
Fertilize	7.89
1. Sub-total	$54.82
2. Miscellaneous Overhead Five percent of line 1	2.74
3. Total Operations	$57.56
4. Management (Ten percent of line 3)	5.76
5. Total Management & Operations	$63.32
Interest on Operating Capital	3.17
TOTAL	$66.49

* Major reference - Bulletin 1058 of the Montana Cooperative Extension Service.

FEED BARLEY*

Costs:

Plow	5.20
Spike harrow (2)	1.81
Seed, harrow	7.63
Fertilizer (custom)	11.00
Make borders	2.00
Irrigate (2)	1.16
Spray	1.61
Swath (custom)	2.50
Combine (custom)	8.00
Bale Straw	2.21
Haul	6.72
1. Sub-totals	$49.84
2. Miscellaneous Overhead Five percent of line 1	2.49
3. Total Operations	$52.33
4. Management (Ten percent of line 3	5.23
5. Total Management & Operation	$57.56
Interest on Operating Capital	2.88
TOTAL	$60.44

* Major reference is Bulletin 1069 of the Montana Cooperative Extension Service.

CORN SILAGE*

Direct Operating Costs:

Fertilizer	19.20
Plow	5.20
Mulch w/roller harrow	2.43
Spring Tooth	2.67
Plant	3.63
Seed	5.60
Harrow	.17
Dig Laterals	.67
Spray Weeds	1.13
Chemical	.48
Cultivate	2.42
Spray Weeds	1.13
Chemical	.48
Cultivate	2.42
Irrigate	1.75
Chop	19.74
Haul	25.88
Pack	5.89
1. Sub-Total	$100.89
2. Decrease Billings operation 15 percent	85.76
3. Miscellaneous Overhead Five percent of line 2	4.28
4. Total Operations	$90.04
5. Management (Ten percent of line 4)	9.00
6. Total Management & Operations	$99.04
Interest on Operating Capital	4.95
TOTAL	$103.99

YIELD: 15 to 20 tons

PRICE: $6.00 to $8.00 per ton

* Major reference from Bulletin 1069 of Montana Cooperative Extension Service.

For study area 11-12 tons per acre expected yield in contrast to 15-17 in Yellowstone Valley. Cost for Yellowstone assumed to reflect more intensive requirements & cost for area than assumed 15 percent less than for Yellowstone area. No reflection made as to increased transportation costs in study area as location of market uncertain of large acreages of corn were to be made available.

SUGAR BEETS*

Direct Operating Costs:

Load manure	5.80
Haul manure	14.65
Disk	1.23
Plow	5.20
Mulch (2)	2.43
Float (3)	5.99
Fertilizer	24.24
Spread Custom	1.50
Plant	16.01
Seed	5.00
Ditch	.55
Irrigate (.3)	.26
Harrow (.3)	.59
Dig Laterals	.70
Cultivate	5.50
Roll	1.49
Spray	1.80
Cultivate (4)	9.77
Irrigate (5)	4.38
Thin	17.80
Hoe	10.50
Save tops	10.02
Harvest beets	18.19
Haul beets	18.85
1. Sub-Total	$182.45
2. Decrease Billings operation 15 percent	155.08
3. Miscellaneous Overhead Five percent of line 2	7.75
4. Total Operations	$162.83
5. Management (Ten percent of line 4)	16.28
6. Total Management & Operation	$179.11
Interest on Operting capital	8.96
TOTAL	$188.07

YIELD: 11 to 12 tons

PRICE: $15 to 20 per ton

* Major reference from Bulletin 1069 of Montana Cooperative Extension Service.

For study area 11-12 tons per acre expected yield in contrast to 15-17 in Yellowstone Valley. Cost for Yellowstone assumed to reflect more intensive requirements & cost for area than assumed 15 percent less than for Yellowstone area. No reflection made as to increased transportation costs in study area as location of market uncertain of large acreages of beets were available.

POTATOES

Specialists with the Montana Cooperative Extension Service at Montana State University who are associated with work concerning irrigated potatoes have aided us in supplying the following information concerning the costs, yields and prices of potatoes.

The estimated cost - $225 to $275 per acre

Estimated Yield - 350 sacks per acre

Estimated Price - $2.50 to $3.00 per sack

The costs have not been estimated by costing out each individual operation as with the other crops. The following is, however, a list of the operations that would likely by associated with the growing of potatoes in the study area:

Plow

Disc (Rototill)

Harrow

Plant

Fertilize - 120-150 pounds of nitrogen
60 - 80 pounds phosphorous
potash - even for quality

Seed rating - 20-25 sacks per acre

Seed cost - $4.00 per 100 pounds

Insecticide - (Thimate, Dysystem) 3 pounds per acre

You would have a cultivation before the plants are up with a harrow. Two cultivations should follow to form hils and a fourth cultivation leaving furrows. You would apply a herbicide of Eptam at 3 pounds per acre. Irrigate every

5-7 days with 1-2 inches of water. Apply vine killer at $10 to $30 per acre. Harvest with two row harvesters at a new cost of $20,000 and a crew of 3-6 people to operate them. It would require 75-85 horsepower tractor. You will have the hauling costs associated with the trucks depending upon the distance to market. You need 2.4 cu. ft. cellers piling them 10-12 feet deep.

Two good producers in the Manhattan area would be John Schutter and Wilbur Kimm.

We feel for our purposes the costs, yields and prices of $225-$275 per acre with a yield of 350 sacks per acre at $2.50 to $3.50 per acre are sufficient estimates for purposes being used in this study.

TAP INC

ECONOMIC CONSULTANTS

P.O. Box 471 25 East Mendenhall, Bozeman, Montana 59715 Ph. Area 406 587 4461

July 21, 1970

MEMO

TO: Robert D. Catton, P.E.
Henningson, Durham & Richardson, Inc.
3555 Farnam Street
Omaha, Nebraska 68131

FROM: Lloyd C. Rixe, President
T.A.P., Inc.
Box 471
Bozeman, MT 59715

RE: Expected Yields in the North Central Conservancy District Study Area

Attached to this memo you will find a series of tables which outline the yields of winter wheat, spring wheat, durum wheat and barley for the years 1958 to 1967 for the counties of Blaine, Liberty, Chouteau, Phillips, Glacier, Pondera, Hill, Toole and Valley.

You should note that there is a considerable amount of variance in these yields depending upon a variety of factors, many of which are associated with weather and outside of the direct control of the operator.

This data is all based upon the material published by the Montana Crop and Livestock Reporting Service.

Also shown for each one of the counties is the dry land and irrigated acres as well as the yields of each of the principal crops as reported in the agricultural statistics for 1967. The 1968 livestock numbers in the counties are also shown for the categories of cattle-calves, cows for milk, hogs and pigs, sheep and lambs and chickens.

There is also a small amount of data as published from 1964 census concerning the land in farms, the average value per acre and value per farm as well as size of farm.

Lloyd C. Rixe (ps)
Lloyd C. Rixe
President

LCR:ps

BLAINE COUNTY

Year	Winter Wheat Yield / Acre Irrigated Plant.	Har.	Dryland Plant.	Har.	Spring Wheat Yield / Acre Irrigated Plant.	Har.	Dryland Plant.	Har.	Durum Wheat Yield / Acre Irrigated Plant.	Har.	Dryland Plant.	Har.	Barley Yield Per Acre Irrigated Plant.	Har.	Dryland Plant.	Har
1958			18.6	19.	29.1	30.0	12.9	13.0	32.0	32.0	13.0	13.0	30.3	31.0	17.2	18.0
1959			14.9	22.	30.2	31.0	14.8	15.0			18.0	18.0	34.1	38.0	22.8	24.0
1960			19.7	21.	29.1	30.0	10.5	11.0			18.0	18.0	34.8	39.0	18.8	19.0
1961			16.5	19.	17.4	23.0	10.1	11.0					26.8	33.0	11.7	13.9
1962	27.	27.	10.5	24.	29.8	32.0	20.4	22.0	27.0	27.0	26.0	26.0	31.2	34.0	23.4	26.0
1963	26.2	32.8	21.1	23.9	26.4	29.3	20.8	21.1	28.0	28.0	23.0	23.0	31.2	42.0	23.0	26.0
1964	26.	26.	18.	25.	28.9	30.0	18.4	18.5			19.5	19.5	29.3	37.0	29.6	30.7
1965	42.	42.	12.1	17.2	21.3	25.0	14.5	16.0			8.0	16.0	34.5	40.0	28.4	32.5
1966	38.	38.	27.5	28.	37.0	37.0	26.7	27.0			20.0	24.0	41.7	49.0	37.0	41.0
1967	32.	32.	20.8	21.5	28.6	30.0	12.8	13.0			14.0	14.0	48.9	55.0	17.3	18.0

BLAINE COUNTY

Crops	Dryland	Irrigated
1. Winter wheat acres	47,300	200
Winter wheat yield	21.5 bu./acre	32 bu./acre
2. Durum wheat acres	400	-0-
Durum wheat yield	14 bu./acre	-0-
3. Spring wheat acres	48,600	2,100
Spring wheat yield	13 bu./acre	30 bu./acre
All Wheat Acres	98,600	
All Wheat Yield	17.5 bu./acre	
4. Corn Silage acres	100	900
Corn sialge yield	5 t./acre	16 t./acre
5. Flaxseed acres	500	
Flaxseed yield	6 bu./acre	
6. Oats acres	2,300	900
Oats yield	24 bu./acre	47 bu./acre
7. Barley acres	40,600	2,400
Barley yield	18 bu./acre	55 bu./acre
8. Sugar beets acres		930
Sugar beets yield		13.8 t./acre
9. All hay acres	21,800	36,900
All Hay yield	1,16 t./acre	2.21 t./acre
10. Potatoes acres	4	83
Potatoes yield	35 cwt/acre	83 cwt/acre
Livestock (1968)		
Cattle & Calves	91,000	
Cows kept for milk	900	
Hogs & pigs	6,000	

BLAINE COUNTY CONT.

Livestock cont.

Sheep & Lambs	27,000
Chickens	26,000

1964 Census

1.	Pastures	405,566
2.	Acres summerfallow	144,873
3.	Acres harvested	207,623
4.	Not harvested, Not pastured	155,459
5.	Total acres (Farm)	2,484,000
6.	Average value per acre	$30.00
7.	Average value per farm	$121,000
8.	Average size of farm	4,018

Year	Winter Wheat Yield / Acre Irrigated Plant.	Har.	Dryland Plant.	Har.	Spring Wheat Yield / Acre Irrigated Plant.	Har.	Dryland Plant.	Har.	Durum Wheat Yield / Acre Irrigated Plant.	Har.	Dryland Plant.	Har.	Barley Yield Per Acre Irrigated Plant.	Har.	Dryland Plant.	Har.
1958			28.2	28.5	33.0	33.0	30.4	31.0			31.0	31.0	30.9	34.0	42.2	43.0
1959			26.6	29.0	33.0	33.0	18.9	19.0			18.4	20.0	31.5	42.0	32.7	33.0
1960			27.6	28.0	33.0	33.0	15.8	16.0			14.0	14.0	36.0	36.0	25.7	26.5
1961			21.2	22.0	28.0	28.0	11.0	12.0			11.0	11.0	23.3	35.0	15.5	17.0
1962			18.1	22.0	32.0	32.0	21.1	22.0			19.6	20.0	32.0	36.0	29.8	31.0
1963	29.0	29.0	21.2	23.0	28.0	28.0	11.5	13.0			13.5	14.0	34.0	34.0	23.2	26.0
1964	42.0	42.0	28.7	32.0	38.0	38.0	19.7	21.0			22.9	23.5	37.0	37.0	32.1	35.0
1965	65.0	65.0	32.3	35.5	24.0	24.0	21.2	21.5			25.2	27.0	60.0	68.5	36.1	41.1
1966	24.0	36.0	32.4	33.0	40.0	40.0	27.4	28.0			28.0	28.0	45.8	50.0	44.2	46.0
1967	38.0	38.0	32.2	32.9	37.0	37.0	18.8	19.0			16.0	16.0	46.0	46.0	30.2	31.0

CHOUTEAU COUNTY

Crops	Dryland	Irrigated
1. Winter wheat acres	431,600	400
Winter wheat yield	33 bu./acre	38 bu./acre
2. Durum wheat acres	1,700	-0-
Durum wheat yield	16 bu./acre	-0-
3. Spring wheat acres	27,700	100
Spring wheat yield	19 bu./acre	37 bu./acre
All wheat acres	461,500	
All wheat yield	32.1 bu./acre	
4. Corn silage acres	200	100
Corn silage yield	6 t./acre	14 t./acre
5. Flaxseed acres	200	
Flaxseed yield	9 bu./acre	
6. Oats acres	4,000	100
Oats yield	26 bu./acre	50 bu./acre
7. Barley acres	92,800	800
Barley yield	31 bu./acre	46 bu./acre
8. Sugar beets acres	--	--
Sugar beets yield	--	--
9. All hay acres	32,300	8,700
All hay yield	1.26 t./acre	1.75 t./acre
10. Potatoes acres	--	--
Potatoes yield	--	--
Livestock (1968)		
Cattle & Calves	70,000	
Cows kept for milk	400	

CHOUTEAU COUNTY CONT.

Livestock cont.

Hogs & Pigs	4,400
Sheep & Lambs	3,900
Chickens	32,000

1964 Census

1.	Pastures	1,325,203
2.	Acres summerfallow	526,823
3.	Acres harvested	537,539
4.	Not harvest, Not pastured	595,116
5.	Total acres (Farm)	2,493,000
6.	Average value per acre	$63.00
7.	Average value per farm	$170,000
8.	Average size of farm (acres)	2,691

GLACIER COUNTY

Year	Winter Wheat Yield / Acre Irrigated Plant.	Har.	Dryland Plant.	Har.	Spring Wheat Yield / Acre Irrigated Plant.	Har.	Dryland Plant.	Har.	Durum Wheat Yield / Acre Irrigated Plant.	Har.	Dryland Plant.	Har.	Barley Yield Per Acre Irrigated Plant.	Har.	Dryland Plant.	Har
1958			34.7	35.0	42.0	42.0	31.2	31.5			34.0	34.0	30.0	30.0	27.8	28.0
1959			24.5	25.0	35.0	35.0	18.9	19.0			20.0	20.0	33.0	33.0	50.4	52.0
1960			21.4	22.0	36.0	36.0	17.9	18.0			16.0	16.0	32.0	32.0	27.6	28.0
1961			24.9	27.0	43.0	43.0	18.1	19.0			12.8	17.0	38.7	41.5	19.6	20.2
1962			12.2	21.0	30.0	30.0	21.5	22.0			16.6	17.0	40.8	42.0	28.4	29.0
1963	34.0	34.0	12.7	21.0	30.8	30-8	17.3	18.1			15.4	16.0	38.0	38.0	30.5	32.0
1964	41.0	41.0	32.2	34.0	29.0	29.0	23.7	24.1	27.0	27.0	26.0	26.0	43.1	45.0	36.2	36.8
1965			32.2	35.0	36.0	36.0	29.7	30.0			26.0	26.0	60.5	60.5	41.3	43.1
1966	40.0	40.0	33.4	34.0	37.0	37.0	25.4	26.0			26.4	27.0	46.3	48.0	42.8	43.0
1967	40.0	40.0	28.6	2910	32.0	32.0	17.9	18.0			19.5	21.0	48.0	48.0	26.7	29.0

GLACIER COUNTY

	Crops	Dryland	Irrigated
1.	Winter wheat acres	27,000	200
	Winter wheat yield	29 bu./acre	40 bu./acre
2.	Durum wheat acres	5,300	-0-
	Durum wheat yield	21 bu./acre	-0-
3.	Spring wheat acres	32,300	300
	Spring wheat yield	18 bu./acre	32 bu./acre
	All wheat acres	65,100	
	All wheat yield	22.9 bu./acre	
4.	Corn silage acres	--	--
	Corn silage yield	--	--
5.	Flaxseed acres	200	
	Flaxseed yield	10 bu./acre	
6.	Oats acres	2,500	
	Oats yield	25 bu./acre	
7.	Barley acres	79,800	1,700
	Barley yield	29 bu./acre	48 bu./acre
8.	Sugar beets acres	--	--
	Sugar beets yield	--	--
9.	All hay acres	28,000	8,500
	All hay yield	.86 t./acre	1.85 t./acre
10.	Potatoes acres	--	--
	Potatoes yield	--	--

Livestock (1968)	
Cattle & Calves	45,000
Cows kept for milk	200
Hogs & Pigs	1,600

GLACIER COUNTY CONT.

Livestock cont

Sheep & lambs	14,000
Chickens	25,000

1964 Census

1.	Pastures	1,214,246
2.	Acres summerfallow	143,511
3.	Acres harvested	188,011
4.	Not harvested, Not pastured	167,043
5.	Total acres (farm)	1,591,000
6.	Average value per acre	$21.00
7.	Average value per farm	$174,000
8.	Average size of farm-acres	3,938

HILL COUNTY

Year	Winter Wheat Yield / Acre				Spring Wheat Yield / Acre				Durum Wheat Yield / Acre				Barley Yield Per Acre			
	Irrigated		Dryland		Irrigated		Dryland		Irrigated		Dryland		Irrigated		Dryland	
	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har
1958	33.0	33.0	25.2	25.5	40.0	40.0	24.8	25.0			28.0	28.0	31.0	31.0	33.8	34.0
1959			24.2	27.0	30.0	30.0	18.9	19.0			21.0	21.0	27.0	36.0	30.7	31.0
1960			26.6	27.0	32.0	32.0	14.9	15.0			13.7	14.0			22.8	23.5
1961			18.4	19.0	32.0	32.0	7.8	8.0			5.1	8.0	35.0	35.0	11.8	13.0
1962			10.7	17.0	30.0	30.0	14.4	15.0			11.2	12.0	36.0	36.0	22.1	23.0
1963			16.3	18.0	28.0	28.0	12.7	14.0			13.7	14.0	38.0	38.0	16.9	18.0
1964			17.0	21.5	50.0	50.0	16.6	17.5			17.6	19.0	42.0	42.0	25.3	28.0
1965			24.9	26.5	22.0	22.0	15.1	16.5			13.6	14.5	24.7	37.0	31.5	34.0
1966			29.3	30.0	32.0	32.0	23.7	24.0	8.7	26.0	19.2	21.0	29.3	44.0	39.6	40.5
1967			21.5	22.0	28.0	28.0	13.9	14.0			12.8	13.0			17.9	19.0

HILL COUNTY

	Crops	Dryland	Irrigated
1.	Winter wheat acres	339,500	-0-
	Winter wheat yield	22 bu./acre	-0-
2.	Durum wheat acres	5,700	-0-
	Durum wheat yield	13 bu./acre	-0-
3.	Spring wheat acres	78,900	100
	Spring wheat yield	14 bu./acre	28 bu./acre
	All wheat acres	424,200	
	All wheat yield	20.4 bu./acre	
4.	Corn silage acres	200	600
	Corn silage yield	4 t./acre	12 t./acre
5.	Flaxseed acres	200	
	Flaxseed yield	6 bu./acre	
6.	Oats acres	2,200	300
	Oats yield	16 bu./acre	34 bu./acre
7.	Barley acres	77,500	
	Barley yield	19 bu./acre	
8.	Sugar beets acres	--	--
	Sugar beets yield	--	--
9.	All hay acres	20,200	5,700
	All hay yield	.68 t./acre	1.96 t./acre
10.	Potatoes acres	--	--
	Potatoes yield	--	--
	Livestock (1968)		
	Cattle & Calves	37,000	
	Cows kept for milk	500	
	Hogs & Pigs	1,500	

HILL COUNTY CONT.

Livestock cont.

Sheep & Lambs	2,200
Chickens	21,000

1964 Census

1.	Pastures	720,405
2.	Acres summerfallow	526,561
3.	Acres harvested	473,968
4.	Not harvested, Not pastured	583,269
5.	Total acres (Farm)	1,804,000
6.	Average value per acre	$58.00
7.	Average value per farm	$136,000
8.	Average size of farm (acres)	2,325

LIBERTY COUNTY

Year	Winter Wheat Yield / Acre				Spring Wheat Yield / Acre				Durum Wheat Yield / Acre				Barley Yield Per Acre			
	Irrigated		Dryland		Irrigated		Dryland		Irrigated		Dryland		Irrigated		Dryland	
	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har
1958			30.7	31.0			29.8	30.0			28.0	28.0			44.6	46.0
1959			24.3	27.0			19.9	20.0			18.0	18.0	44.0	44.0	35.6	36.0
1960			24.7	25.0			15.7	16.0			14.9	15.0			25.8	26.0
1961			10.9	14.0			8.6	9.0			9.9	10.0			112.	13.0
1962			5.2	11.0			6.2	8.0			7.0	8,0	.		9.8	12.0
1963			10.1	12.0			10.2	11.0			10.6	11.0			13.2	15.0
1964			13.4	20.0			15.7	16.5			16.8	18.0	41.0	41.0	23.7	27.0
1965			32.3	34.0			22.0	23.0			17.8	18.5			34.5	37.0
1966			36.9	38.0			26.7	27.0			26.1	27.6			43.9	45.0
1967			23.1	23.5			14.4	14.5			15.7	16.0			19.5	20.0

LIBERTY COUNTY

Crops		Dryland	Irrigated
1.	Winter wheat acres	137,200	-0-
	Winter wheat yield	23.5 bu/acre	-0-
2.	Durum wheat acres	10,100	-0-
	Durum wheat yield	16 bu./acre	-0-
3.	Spring wheat acres	72,400	-0-
	Spring wheat yield	14.5 bu/acre	-0-
	All wheat acres	219,700	
	All wheat yield	20.2 bu./acre	
4.	Corn silage acres	--	--
	Corn silage yield	--	--
5.	Flaxseed acres	--	--
	Flaxseed yield	--	--
6.	Oats acres	2,700	
	Oats yield	20 bu./acre	
7.	Barley acres	66,400	
	Barley yield	20 bu./acre	
8.	Sugar beets acres	--	--
	Sugar beets yield	--	--
9.	All hay acres	8,700	2,300
	All hay yield	.9 t./acre	1.83 t./acre
10.	Potatoes acres	--	--
	Potatoes yield	--	--

Livestock (1968)	
Cattle & Calves	17,000
Cows kept for milk	200
Hogs & Pigs	1,200

LIBERTY CONT.

Livestock Cont.

Sheep & Lambs	2,800
Chickens	12,000

1964 Census

1.	Pastures	390,343
2.	Acres summerfallow	272,926
3.	Acres harvested	258,069
4.	Not harvested, Not pastured	295,249
5.	Total acres (farm)	949,000
6.	Average value per acre	$61.00
7.	Average value per farm	$184,000
8.	Average size of farm (acres)	3,004

PHILLIPS COUNTY

Year	Winter Wheat Yield / Acre				Spring Wheat Yield / Acre				Durum Wheat Yield / Acre				Barley Yield Per Acre			
	Irrigated		Dryland		Irrigated		Dryland		Irrigated		Dryland		Irrigated		Dryland	
	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har
1958	30.0	30.0	14.6	15.0	29.0	29.0	13.6	14.0			18.0	18.0	35.1	41.0	17.1	19.0
1959			7.0	17.0	24.5	28.0	11.9	12.0			9.2	11.0	28.5	34.0	14.6	15.1
1960			18.8	19.0	29.7	36.0	10.8	11.0			12.0	12.0	29.6	37.0	14.8	16.0
1961			8.4	12.0	22.1	31.0	8.6	10.0			12.0	12.0	11.6	36.0	13.2	15.8
1962	12.5	25.0	4.6	14.0	22.1	24.0	22.6	23.0			27.0	27.0	26.4	36.0	25.4	28.0
1963	40.0	40.0	32.2	34.0	30.9	32.0	26.8	27.0			21.4	23.0	34.6	42.0	35.7	37.1
1964	30.0	30.0	22.7	24.0	29.1	32.0	19.9	20.1			20.0	20.0	32.1	39.0	32.2	32.7
1965	35.0	35.0	12.2	16.9	23.0	23.0	19.8	20.0			16.5	16.5	38.5	42.0	31.2	32.0
1966			24.4	25.0	29.1	36.0	21.7	22.0	31.0	31.0	25.0	25.0	45.8	50.0	32.2	33.0
1967	28.0	28.0	21.3	22.0	23.2	29.0	12.3	12.5			15.0	15.0	36.0	40.0	18.0	19.0

PHILLIPS COUNTY

	Crops	Dryland	Irrigated
1.	Winter wheat acres	22,100	-0-
	Winter wheat yield	22 bu./acre	-0-
2.	Durum wheat acres	1,400	-0-
	Durum wheat yield	15 bu./acre	-0-
3.	Spring wheat acres	76,900	800
	Spring wheat yield	12.5 bu./acre	29 bu./acre
	All wheat acres	101,400	
	All wheat yield	14.8 bu./acre	
4.	Corn silage acres	100	600
	Corn silage yield	4 t./acre	19.5 t./acre
5.	Flaxseed acres	--	--
	Flaxseed yield	--	--
6.	Oats acres	3,300	1,200
	Oats yield	22 bu./acre	50 bu./acre
7.	Barley acres	24,300	900
	Barley yield	19 bu./acre	40 bu./acre
8.	Sugar beets acres		160
	Sugar beets yield		12.5 t./acre
9.	All hay acres	39,800	33,700
	All hay yield	.89 t./acre	1.88 t./acre
10.	Potatoes acres	--	--
	Potatoes yield	--	--
	Livestock (1968)		
	Cattle & Calves	98,000	
	Cows kept for milk	600	
	Hogs & Pigs	7,000	

PHILLIPS COUNTY CONT.

Livestock cont.

Sheep & Lambs	19,000
Chickens	14,000

1964 Census

1.	Pastures	1,925,168
2.	Acres summerfallow	143,668
3.	Acres harvested	199,730
4.	Not harvested, not pastured	159,859
5.	Total acres (farm)	2,274,000
6.	Average value per acre	$23.00
7.	Average value per farm	$83,000
8.	Average size of farm (acres)	3,662

PONDERA COUNTY

Year	Winter Wheat Yield / Acre				Spring Wheat Yield / Acre				Durum Wheat Yield / Acre				Barley Yields Per Acre			
	Irrigated		Dryland		Irrigated		Dryland		Irrigated		Dryland		Irrigated		Dryland	
	Plant.	Har	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.
1958	35.2	38.0	36.4	37.0	36.0	36.0	31.3	32.0			29.5	30.0	42.4	45.0	41.8	43.0
1959	35.5	42.0	30.2	32.0	33.0	33.0	21.9	22.0	39.0	39.0	21.9	22.0	42.3	43.0	34.1	34.3
1960	39.5	42.0	25.3	26.0	29.0	29.0	17.8	18.0	20.3	23.0	17.8	18.0	40.4	41.0	27.2	27.5
1961	40.0	40.0	24.0	26.0	21.0	21.0	14.0	14.0	28.0	28.0	18.8	19.0	38.2	40.0	24.6	25.0
1962	33.0	36.0	12.7	19.0	25.6	27.0	13.8	14.0	33.6	36.0	14.9	15.0	47.5	48.0	25.0	25.3
1963	21.7	34.5	13.6	20.0	29.0	29.0	11.2	12.2	24.0	24.0	12.4	14.0	44.0	44.0	21.4	23.6
1964	43.6	50.5	35.0	37.5	33.0	33.0	26.1	26.6	41.0	41.0	27.6	28.3	47.7	51.0	39.0	40.5
1965	58.4	60.0	3618	38.8	42.0	42.0	30.5	31.0	41.0	41.0	36.7	37.0	57.4	58.5	47.8	49.3
1966	39.5	45.0	35.3	37.0	30.0	30.0	26.1	27.0	34.0	34.0	27.7	28.0	51.4	52.0	47.1	48.0
1967	38.9	40.5	31.3	32.0	26.5	26.5	21.9	22.0	41.0	41.0	21.8	22.0	56.3	59.0	3017	31.0

PONDERA COUNTY

	Crops	Dryland	Irrigated
1.	Winter wheat acres	126,300	2,500
	Winter wheat yield	32 bu./acre	40.5 bu./acre
2.	Durum wheat acres	20,900	300
	Durum wheat yield	22 bu./acre	41 bu./acre
3.	Spring wheat acres	27,000	800
	Spring wheat yield	22 bu./acre	26.5 bu./acre
	All wheat acres	177,800	
	All wheat yield	29.4 bu./acre	
4.	Corn silage acres	--	--
	Corn silage yield	--	--
5.	Flaxseed acres	--	--
	Flaxseed yield	--	--
6.	Oats acres	2,000	700
	Oats yield	25 bu./acre	40 bu./acre
7.	Barley acres	75,400	4,100
	Barley yield	31 bu./acre	59 bu./acre
8.	Sugar beets acres	--	--
	Sugar beets yield	--	--
9.	All hay acres	15,700	14,200
	All hay yield	1,18 t./acre	2.3 t./acre
10.	Potatoes acres	--	--
	Potatoes yield	--	--

Livestock (1968)	
Cattle & Calves	35,000
Cows kept for milk	600
Hogs & Pigs	5,800

PONDERA COUNTY CONT

Livestock cont.

Sheep & Lambs	11,500
Chickens	22,000

1964 Census

1.	Pastures	357,820
2.	Acres summerfallow	261,607
3.	Acres harvested	275,857
4.	Not harvested, not pastured	277,247
5.	Total acres (farm)	921,000
6.	Average value per acre	$98.00
7.	Average value per farm	$150,000
8.	Average size of farm (acres)	1,510

TOOLE COUNTY

Year	Winter Wheat Yield / Acre				Spring Wheat Yield / Acre				Durum Wheat Yield / Acre				Barley Yield Per Acre			
	Irrigated		Dryland		Irrigated		Dryland		Irrigated		Dryland		Irrigated		Dryland	
	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har
1958			36.6	37.0			30.7	31.0			31.0	31.0			49.5	50.0
1959			20.5	25.0			19.8	20.0			16.9	17.0			29.5	30.0
1960			24.3	25.0			13.7	14.0			13.5	140			18.1	19.6
1961			14.0	16.0			8.9	11.0			6.0	8.0			10.5	14.0
1962			8.0	16.0			11.4	13.0			11.8	12.0	36.0	54.0	16.3	19.0
1963			7.4	13.0			6.9	9.0			8.7	10.0			12.3	16.0
1964			25.2	27.5			20.2	20.5			20.4	21.0	42.0	42.0	30.0	32.0
1965			28.8	32.0			25.3	25.5			29.2	30.0			42.0	43.0
1966			36.4	37.0			29.8	30.0			26.8	27.0			44.6	45.0
1967			26.4	27.5			17.8	18.0			18.1	18.5			23.6	25.0

TOOLE COUNTY

	Crops	Dryland	Irrigated
1.	Winter wheat acres	77,300	-0-
	Winter wheat yield	27.5 bu./acre	-0-
2.	Durum wheat acres	10,000	-0-
	Durum wheat yield	18.5 bu./acre	-0-
3.	Spring wheat acres	101,700	-0-
	Spring wheat yield	18 bu./acre	-0-
	All wheat acres	189,000	
	All wheat yield	21.9 bu./acre	
4.	Corn silage acres	--	--
	Corn silage yield	--	--
5.	Flaxseed acres	--	--
	Flaxseed yield	--	--
6.	Oats acres	2,300	--
	Oats yield	20 bu/acre	--
7.	Barley acres	102,800	
	Barley yield	25 bu./acre	
8.	Sugar beets acres	--	--
	Sugar beets yield	--	--
9.	All hay acres	12,700	1,800
	All hay yield	.9 t./acre	1.83 t./acre
10.	Potatoes acres	--	--
	Potatoes yield	--	--

Livestock (1968)	
Cattle & Calves	23,000
Cows kept for milk	200
Hogs & Pigs	2,100

TOOLE COUNTY CONT

Livestock cont.

Sheep & Lambs	7,600
Chickens	17,000

1964 Census

1. Pastures	503,208
2. Acres summerfallow	253,068
3. Acres harvested	301,863
4. Not harvested, Not pastured	339,615
5. Total acres (farm)	1,177,000
6. Average value per acre	$62.00
7. Average value per farm	$175,000
8. Average size of farm (acres)	2,795

VALLEY COUNTY

Year	Winter Wheat Yield / Acre				Spring Wheat Yield / Acre				Durum Wheat Yield / Acre				Barley Yield Per Acre			
	Irrigated		Dryland		Irrigated		Dryland		Irrigated		Dryland		Irrigated		Dryland	
	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.	Plant.	Har.
1958			12.6	13.0	22.0	22.0	10.6	11.0			8.6	9.0	30.0	30.0	13.8	15.0
1959			1.1	11.0	25.0	26.0	11.9	12.0	36.0	36.0	12.8	13.0	34.7	36.0	15.7	15.9
1960			14.6	18.0	21.3	23.0	18.8	19.0	34.0	34.0	13.9	14.0	20.5	25.0	19.0	20.6
1961			6.6	10.0	21.1	23.0	5.5	6.0	15.6	28.0	6.7	7.0	14.2	23.0	6.0	8.0
1962	25.0	25.0	3.6	15.0	30.5	31.3	21.2	21.9	22.5	15.0	19.7	20.0	22.7	27.0	24.8	26.0
1963	36.7	36.7	33.3	35.0	30.6	33.2	25.7	25.9	38.0	38.0	23.4	24.0	39.7	42.0	36.7	37.0
1964	31.0	31.0	24.5	25.4	28.2	29.0	19.2	19.9	42.0	42.0	22.7	23.1	35.6	38.0	31.8	33.9
1965	40.0	40.0	7.6	14.9	24.0	24.0	22.3	22.5	38.0	38.0	26.2	27.0	42.6	45.0	34.0	34.5
1966	38.0	38.0	24.0	25.0	24.6	28.0	21.7	22.0	28.0	28.0	21.0	21.0	31.8	46.0	31.1	32.0
1967	30.0	30.0	24.5	25.0	21.6	23.0	15.4	15.5	36.0	36.0	12.6	13.0	36.6	39.0	21.6	22.0

VALLEY COUNTY

	Crops	Dryland	Irrigated
1.	Winter wheat acres	14,300	200
	Winter wheat yield	25 bu./acre	30 bu./acre
2.	Durum wheat acres	5,900	300
	Durum wheat yield	13 bu./acre	36 bu./acre
3.	Spring wheat acres	240,000	3,200
	Spring wheat yield	15.5 bu./acre	23 bu./acre
	All wheat acres	263,900	
	All wheat yield	16.1 bu./acre	
4.	Corn silage acres	100	700
	Corn silage yield	5 t./acre	16 t./acre
5.	Flaxseed acres	200	
	Flaxseed yield	5 bu./acre	
6.	Oats acres	3,300	500
	Oats yield	23 bu./acre	56 bu./acre
7.	Barley acres	56,500	1,500
	Barley yield	22 bu./acre	39 bu./acre
8.	Sugar beets acres	--	--
	Sugar beets yield	--	--
9.	All hay acres	37,200	22,000
	All ahy yield	.87 t./acre	2.54 t./acre
10.	Potatoes acres	--	--
	Potatoes yield	--	--

Livestock (1968)	
Cattle & Calves	92,000
Cows kept for milk	700
Hogs & Pigs	3,700

VALLEY COUNTY CONT.

Livestock cont

Sheep & Lambs	21,000
Chickens	39,000

1964 Census

1.	Pastures	1,651,603
2.	Acres summerfallow	308,816
3.	Acres harvested	344,176
4.	Not harvested, not pastured	352,002
5.	Total acres (farm)	3,352,000
6.	Average value per acre	$39.00
7.	Average value per farm	$103,000
8.	Average size of farm (acres)	2,651

APPENDIX G

MONTANA WATER QUALITY STANDARDS

ADOPTED BY THE MONTANA WATER POLLUTION CONTROL COUNCIL, OCTOBER 5, 1967.

STATE OF MONTANA WATER POLLUTION CONTROL COUNCIL

WATER QUALITY CRITERIA

APPLICABLE AFTER REASONABLE OPPORTUNITY FOR DISCHARGES TO MIX WITH RECEIVING WATERS AS DETERMINED BY THE MONTANA WATER POLLUTION CONTROL COUNCIL.

NOTE: QUALITATIVE AND QUANTITATIVE EVALUATION OF WATER SAMPLES FOR COMPARISON WITH THESE CRITERIA SHOULD BE MADE IN ACCORDANCE WITH PROCEDURES SET FORTH IN THE TWELFTH EDITION OF "STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER", APHA, AWWA, AND WPCF, 1965.

WATER QUALITY CRITERIA WATER USE	ORGANISMS OF THE COLIFORM GROUP BY THE MOST PROBABLE NUMBER OR EQUIVALENT MEMBRANE FILTER METHODS, DURING ANY CONSECUTIVE 30-DAY PERIOD, AND USING A REPRESENTATIVE NUMBER OF SAMPLES, SHALL:	DISSOLVED OXYGEN MILLIGRAMS/LITER (MG/L) NO REDUCTION SHALL BE ALLOWED BELOW THE LISTED MINIMUM CONCENTRATION.	pH INDUCED VARIATION WITHIN LISTED RANGE SHALL BE LESS THAN 0.5 pH UNIT. NATURAL pH OUTSIDE LISTED RANGE SHALL BE MAINTAINED WITHOUT CHANGE. NATURAL pH ABOVE 7.0 SHALL BE MAINTAINED ABOVE 7.0	TURBIDITY JACKSON CANDLE UNITS (JCU) ALLOWABLE INCREASE TO NATURALLY OCCURRING TURBIDITY	TEMPERATURE (°F) ALLOWABLE CHANGES TO NATURALLY OCCURRING WATER TEMPERATURE	RESIDUES OILS, FLOATING SOLIDS AND SLUDGE DEPOSITS. ALLOWABLE INCREASES ABOVE NATURALLY OCCURRING CONCENTRATIONS.	SEDIMENT OR SETTLEABLE SOLIDS ALLOWABLE INCREASE ABOVE NATURALLY OCCURRING CONCENTRATIONS:	TOXIC OR OTHER DELETERIOUS SUBSTANCES, PESTICIDES AND ORGANIC AND INORGANIC MATERIALS INCLUDING HEAVY METAL COMPOUNDS. (EXCEPTIONS FOR BENEFICIAL PURPOSES MAY BE AUTHORIZED BY THE MONTANA WATER POLLUTION CONTROL COUNCIL AND THE FEDERAL WATER POLLUTION CONTROL ADMINISTRATION)	RADIOACTIVITY (LIMITS LISTED SHALL INCLUDE NATURAL BACKGROUND)	AESTHETIC CONSIDERATIONS NOT COVERED UNDER OTHER WATER QUALITY CRITERIA.
A-CLOSED. WATER SUPPLY FOR DRINKING, CULINARY AND FOOD PROCESSING PURPOSES SUITABLE FOR USE AFTER SIMPLE DISINFECTION. PUBLIC ACCESS AND ACTIVITIES SUCH AS LIVESTOCK GRAZING AND TIMBER HARVEST SHOULD BE STRICTLY CONTROLLED UNDER CONDITIONS PRESCRIBED BY THE STATE BOARD OF HEALTH.	AVERAGE LESS THAN 50 PER 100 MILLILITERS (50/100 ML).	NOT APPLICABLE	NO CHANGE IN NATURAL pH SHALL BE ALLOWED.	NONE	NONE	NONE	NONE	NONE ALLOWED IN ADDITION TO CONCENTRATIONS NATURALLY PRESENT.	NO WASTES SHALL BE ALLOWED WHICH INCREASE RADIOACTIVITY ABOVE NATURAL BACKGROUND.	NO EVIDENCE OF MATTER OTHER THAN THAT NATURALLY OCCURRING.
A-OPEN. WATER SUPPLY FOR DRINKING, CULINARY AND FOOD PROCESSING PURPOSES SUITABLE FOR USE AFTER SIMPLE DISINFECTION AND REMOVAL OF NATURALLY PRESENT IMPURITIES.	AVERAGE LESS THAN 50/100 ML WHERE DEMONSTRATED TO BE THE RESULT OF DOMESTIC SEWAGE	NOT APPLICABLE	6.5 TO 8.5	SAME AS FOR "A-OPEN" ABOVE.	NOT APPLICABLE	NONE IN SUFFICIENT QUANTITIES TO ADVERSELY AFFECT THE USE INDICATED.	NONE IN SUFFICIENT QUANTITIES TO ADVERSELY AFFECT THE USE INDICATED.	CONCENTRATIONS OF CHEMICAL CONSTITUENTS SHALL CONFORM WITH THE 1962 U. S. PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS. INDUCED VARIATIONS WITHIN THESE STANDARDS SHALL BE LIMITED TO AN INCREASE OF NOT MORE THAN TEN PERCENT OF THE CONCENTRATION PRESENT IN THE RECEIVING WATER.	CONCENTRATIONS OF RADIOACTIVE SUBSTANCES SHALL CONFORM WITH THE 1962 U.S. PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS.	NO EVIDENCE OF MATTER OTHER THAN THAT NATURALLY OCCURRING, EXCEPT REAL COLOR SHALL NOT BE INCREASED MORE THAN TWO UNITS ABOVE NATURALLY OCCURRING COLOR.
B. WATER SUPPLY FOR DRINKING, CULINARY AND FOOD PROCESSING PURPOSES SUITABLE FOR USE WITH ADEQUATE TREATMENT EQUAL TO COAGULATION, SEDIMENTATION, FILTRATION, DISINFECTION, AND ANY ADDITIONAL TREATMENT NECESSARY TO REMOVE NATURALLY PRESENT IMPURITIES.	AVERAGE LESS THAN 1000/100 ML WHERE DEMONSTRATED TO BE THE RESULT OF DOMESTIC SEWAGE, WITH NOT MORE THAN 20 PERCENT OF THE SAMPLES EXCEEDING THIS VALUE.	NOT APPLICABLE	6.5 TO 9.5	NONE IN SUFFICIENT QUANTITIES TO ADVERSELY AFFECT ESTABLISHED LEVELS OF TREATMENT.	NOT APPLICABLE	NONE IN SUFFICIENT QUANTITIES TO ADVERSELY AFFECT ESTABLISHED LEVELS OF TREATMENT.	NONE IN SUFFICIENT QUANTITIES TO ADVERSELY AFFECT ESTABLISHED LEVELS OF TREATMENT.	CONCENTRATIONS OF CHEMICAL CONSTITUENTS SHALL CONFORM WITH THE 1962 U.S. PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS AFTER CONVENTIONAL TREATMENT.	SAME AS FOR "A-OPEN" ABOVE.	NO WASTES (INCLUDING PHENOLIC COMPOUNDS AND VISIBLE OILS) OFFENSIVE TO THE SENSES OF SIGHT, TOUCH, SMELL OR TASTE, NOT ATTRIBUTABLE TO NATURAL CAUSES, SHALL BE ALLOWED.
C. BATHING, SWIMMING AND RECREATION	SAME AS FOR "B" ABOVE.	NOT APPLICABLE	SAME AS FOR "B" ABOVE	10 JCU	NOT APPLICABLE	SAME AS FOR "A-OPEN" ABOVE.	SAME AS FOR "A-OPEN" ABOVE.	CONCENTRATIONS OF CHEMICAL CONSTITUENTS SHALL BE MAINTAINED BELOW LEVELS KNOWN TO BE (OR DEMONSTRATED TO BE) OF PUBLIC HEALTH SIGNIFICANCE.	SAME AS FOR "A-OPEN" ABOVE.	SAME AS FOR "B" ABOVE.
D-1. GROWTH AND PROPAGATION OF SALMONID FISHES AND ASSOCIATED AQUATIC LIFE, WATERFOWL AND FURBEARERS.	SAME AS FOR "B" ABOVE.	7 MG/L	SAME AS FOR "A-OPEN" ABOVE	5 JCU	INCREASES. 32° TO 67°: 2° MAXIMUM ABOVE 67° : 0.5° MAX. DECREASES: OVER 55° : 2° PER HOUR 55° TO 32°: 2° MAXIMUM PROVIDED THAT WATER TEMPERATURE MUST BE BELOW 40° DURING THE WINTER SEASON AND ABOVE 44° DURING THE SUMMER SEASON	SAME AS FOR "A-OPEN" ABOVE.	SAME AS FOR "A-OPEN" ABOVE.	MAXIMUM ALLOWABLE CONCENTRATIONS SHALL BE LESS THAN ACUTE OR CHRONIC PROBLEM LEVELS AS REVEALED BY BIOASSAY OR OTHER APPROPRIATE METHODS. IN NO CASE SHALL THE FOLLOWING BE EXCEEDED: ONE-TENTH OF THE FOUR-DAY, MEDIAN TOLERANCE LIMIT (TL_m96) FOR SHORT RESIDUAL MATERIALS AND ONE-HUNDREDTH OF THE TL_m96 FOR PESTICIDES AND ORGANIC MATERIALS EXHIBITING A RESIDUAL LIFE EXCEEDING 30 DAYS IN WATER.	SAME AS FOR "A-OPEN" ABOVE, EXCEPT WHERE CONCENTRATION FACTORS OF AQUATIC FLORA AND FAUNA EXCEED THE RECOMMENDED REDUCTION FACTORS, THEN MAXIMUM PERMISSIBLE LIMITS SHALL BE REDUCED BELOW ACUTE OR CHRONIC PROBLEM LEVELS.	NO WASTES (INCLUDING PHENOLIC COMPOUNDS AND VISIBLE OILS) OFFENSIVE TO THE SENSES OF SIGHT, TOUCH, SMELL OR TASTE, NOT ATTRIBUTABLE TO NATURAL CAUSES, SHALL BE ALLOWED. NO EXCESS NUTRIENTS WHICH CAUSE NUISANCE AQUATIC GROWTHS. TASTE AND ODOR CAUSING MATERIALS SHALL NOT EXCEED LEVELS WHICH CAUSE TAINTING OF THE FLESH OF EDIBLE SPECIES. REAL COLOR SHALL NOT EXCEED FIVE UNITS ABOVE NATURALLY OCCURRING COLOR.
D-2. GROWTH AND MARGINAL PROPAGATION OF SALMONID FISHES AND ASSOCIATED AQUATIC LIFE, WATERFOWL AND FURBEARERS.	SAME AS FOR "B" ABOVE.	6 MG/L	6.5 TO 9.0	SAME AS FOR "C" ABOVE.	SAME AS FOR "D-1" ABOVE.	SAME AS FOR "A-OPEN" ABOVE.	SAME AS FOR "A-OPEN" ABOVE.	SAME AS FOR "D-1" ABOVE.	SAME AS FOR "D-1" ABOVE.	SAME AS FOR "D-1" ABOVE.
D-3. GROWTH AND PROPAGATION OF NON-SALMONID FISHES AND ASSOCIATED AQUATIC LIFE, WATERFOWL AND FURBEARERS.	SAME AS FOR "B" ABOVE.	5 MG/L	SAME AS FOR "B" ABOVE	SAME AS FOR "C" ABOVE.	INCREASES: 32° TO 85°: 4° MAXIMUM ABOVE 85° : 0.5° MAX. DECREASES: SAME AS FOR "D-1" ABOVE. PROVIDED THAT WATER TEMPERATURE MUST BE BELOW 40° DURING THE WINTER SEASON AND ABOVE 44° DURING THE SUMMER SEASON.	SAME AS FOR "A-OPEN" ABOVE.	SAME AS FOR "A-OPEN" ABOVE.	SAME AS FOR "D-1" ABOVE.	SAME AS FOR "D-1" ABOVE	SAME AS FOR "D-1" ABOVE.
E. AGRICULTURAL WATER SUPPLY INCLUDING IRRIGATION, STOCK WATERING AND TRUCK FARMING.	SAME AS FOR "B" ABOVE.	NOT APPLICABLE	SAME AS FOR "B" ABOVE	NONE IN SUFFICIENT QUANTITIES TO ADVERSELY AFFECT THE USE INDICATED.	NOT APPLICABLE	SAME AS FOR "A-OPEN" ABOVE.	SAME AS FOR "A-OPEN" ABOVE.	CONCENTRATIONS SHALL BE LESS THAN THOSE DEMONSTRATED TO BE DELETERIOUS TO LIVESTOCK OR PLANTS OR THEIR SUBSEQUENT CONSUMPTION BY HUMANS.	SAME AS FOR "A-OPEN" ABOVE.	WATER SHALL BE MAINTAINED IN A CONDITION NOT OFFENSIVE TO THE SENSES OF SIGHT AND SMELL.
F. INDUSTRIAL WATER SUPPLY (OTHER THAN FOOD PROCESSING).	NOT APPLICABLE.	NOT APPLICABLE	SAME AS FOR "B" ABOVE	SAME AS FOR "B" ABOVE.	NONE IN SUFFICIENT QUANTITIES TO ADVERSELY AFFECT THE USE INDICATED.	SAME AS FOR "A-OPEN" ABOVE.	SAME AS FOR "B" ABOVE.	NONE IN SUFFICIENT QUANTITIES TO ADVERSELY AFFECT THE USE INDICATED.	SAME AS FOR "A-OPEN" ABOVE.	SAME AS FOR "E" ABOVE.

MONTANA STATE WATER POLLUTION CONTROL COUNCIL

POLICY STATEMENTS

1. Quality of waters classified for multiple use shall be governed by the most stringent criteria listed for any use.

2. The Council has classified as "A-Closed" only those waters on which access and other activities are presently controlled by the utility owner. If other uses are permitted by the utility owner, these waters shall be reclassified "A-Open" or lower. Conversely, waters in the "A-Open" classification, if shown to meet the "A-Closed" criteria, may be so classified by the Council at the request of the utility owner.

   Where "A-Open" water is used for swimming and other water contact sports, a higher degree of treatment may be required for potable water use.

3. The water quality standards are subject to revision (following public hearings and, in the case of interstate streams, concurrence of the Federal Water Pollution Control Administration) as technical data, surveillance programs, and technological advances make such revisions desirable. There are waters in the state on which little water quality data are presently available. Water quality criteria for these waters were established to protect existing and future water uses on the basis of the most representative information available.

   In some cases, particularly in eastern Montana, waters have been classified "B" and "C" where the upper ends of the streams will probably be suitable for this use while the lower ends will not. However, not enough data is available to determine where the "B" and "C" designation should be dropped. Whenever a water supply or swimming area is developed, the regulations and the advice of the State Board of Health should be acquired. As time permits, data will be obtained and the classifications reviewed.

4. As used in the Water Quality Criteria, the phrases "natural," "naturally present," and "naturally occurring" are defined as conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil and water conservation practices have been applied. Waters below existing dams will be considered natural.

5. It is the intent of the criteria that the increase allowed (temperature for example) above natural conditions is the total allowable from all waste sources along the classified stream.

6. Although the water quality criteria specify minimum dissolved oxygen concentrations, it shall be the policy of the Council to require the best practicable treatment or control of all oxygen-consuming wastes in order to maintain dissolved oxygen in the receiving waters at the highest possible level above the specified minimums.

7. For treatment plant design purposes, stream flow dilution requirements shall be based on the minimum consecutive 7-day average flow which may be expected to occur on the average once in 10 years.

8. Where sampling stations and points of mixing of discharges with receiving waters as mentioned in the water quality criteria are to be established on interstate waters, the concurrence of the Federal Water Pollution Control Administration will be solicited.

9. It is not the intent of these criteria to provide for a swimming water immediately below an existing treated domestic sewage outfall.

10. Where common treatment is practicable, it is the policy of the Council to restrict the number of sewer outfalls to a minimum.

11. Tests or analytical procedures to determine compliance with standards will, insofar as practicable and applicable, be made in accordance with the methods given in the twelfth edition of "Standard Methods for the Examination of Water and Waste Water" published by the American Public Health Association, et al, or in accordance with tests or analytical procedures that have been found to be equal or more applicable.

12. Because of conflicting testimony, it is the intent of the Water Pollution Control Council to obtain additional information on temperatures and fisheries on waters below existing steam generating stations at Billings and Sidney on the Yellowstone River. This can probably be best accomplished by a cooperative study between the utility, State Fish and Game Department, Federal Water Pollution Control Administration, and the Montana State Department of Health.

13. Insufficient information is available for establishing fixed sediment criteria at this time. Until standards can be set, reasonable measures, as defined by the Water Pollution Control Council, must be taken to minimize sedimentation from man's activities.

MINIMUM TREATMENT REQUIREMENTS

1. Domestic sewage -- the minimum treatment required for domestic sewage shall be secondary treatment or its equivalent with the understanding that properly designed and operated sewage lagoons will meet this requirement.

2. Industrial wastes -- the minimum treatment required for industrial wastes shall be secondary treatment or its equivalent.

WATER USE DESCRIPTIONS AND APPLICATION

Water use classifications assigned to the Columbia and Missouri Basin and the Hudson Bay drainage in Montana are described as follows:

"A-Closed"--Water supply for drinking, culinary, and food processing purposes, suitable for use after simple disinfection. Public access and activities such as livestock grazing and timber harvest should be strictly controlled under conditions prescribed by the State Board of Health.

The Council has classified as "A-Closed" only those waters on which access is presently controlled by the utility owner. If other uses are permitted by the utility owner, these waters shall be reclassified "A-Open-D_1" or lower.

"A-Open-D_1"--Water supply for drinking, culinary, and food processing purposes suitable for use after simple disinfection and removal of naturally present impurities. Water quality shall also be maintained suitable for the use of these waters for bathing, swimming and recreation (See "Note" below), (where these waters are used for swimming and other water contact sports, a higher degree of treatment may be required for potable water use); growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; agricultural and industrial water supply. Therefore, these waters shall be held suitable for "A-Open", "C", "D", "E", and "F" uses but may not necessarily be used for all such purposes.

Waters in this class, if shown to meet the "A-Closed" criteria, may be so classified by the Council at the request of the utility owner.

All waters within the boundaries of national parks and nationally designated wilderness, wild, or primitive areas in Montana are classified "A-Open-D_1" except those adjacent to developed areas such as Snyder Creek through the community of Lake McDonald and Swiftcurrent Creek below the Many Glacier Chalet, both in Glacier National Park. Also, Georgetown, Flathead, and Whitefish Lakes and Lake Mary Ronan are classified as "A-Open-D_1" as are some streams presently used for domestic water supply.

Note: Common sense dictates that swimming and other water contact sports are inadvisable within a reasonable distance downstream from sewage treatment facility outfalls.

"$B-D_1$" The quality of these waters shall be maintained suitable for drinking, culinary and food processing purposes after adequate treatment equal to coagulation, sedimentation, filtration, disinfection, and any additional treatment necessary to remove naturally present impurities; bathing, swimming, and recreation (see Note under "A-Open-D_1"); growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; agricultural and industrial water supply. Therefore, "$B-D_1$" equals "B", "C", "D_1", "E", and "F".

"$B-D_2$" The quality of these waters shall be maintained suitable for the uses described for "$B-D_1$" waters except that the fisheries use shall be described as follows:

> "Growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers."

Therefore, "$B-D_2$" equals "B", "C", "D_2", "E", and "F".

"$B-D_3$" The quality of these waters shall be maintained suitable for the uses described for "$B-D_1$" waters except that the fisheries use shall be described as follows:

> "Growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers."

Therefore, "$B-D_3$" equals "B", "C", "D_3", "E", and "F".

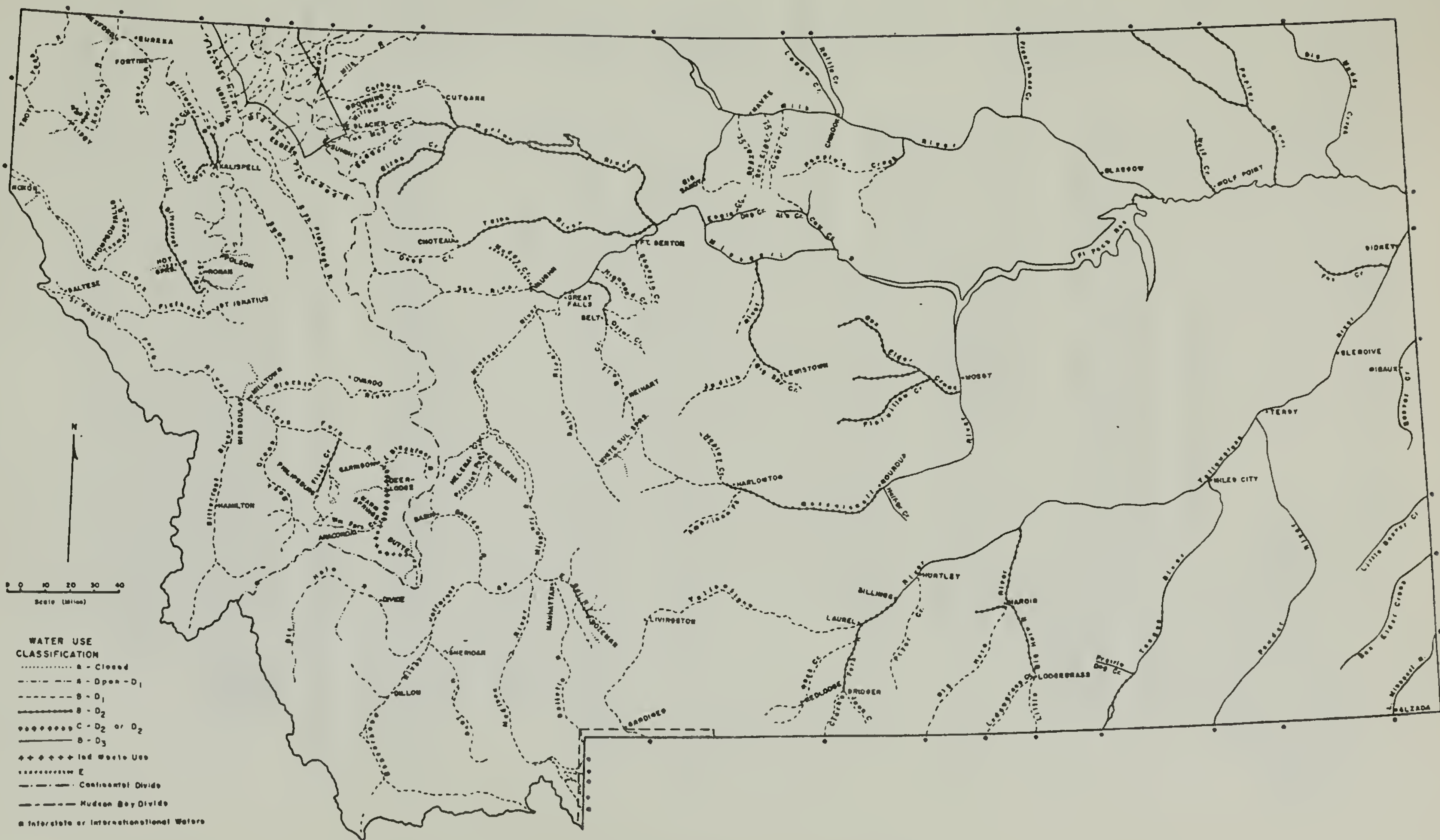
"$C-D_2$" The quality of these waters shall be maintained suitable for bathing, swimming, and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; agricultural and industrial water supply. Therefore, "$C-D_2$" equals "C", "D2", "E", and "F".

"D_2" The quality of these waters shall be maintained for growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; agricultural and industrial water supply. Therefore, "D_2" equals "D_2", "E", and "F".

"E" The quality of these waters shall be maintained for agricultural and industrial water supply uses and "E" shall equal "E" and "F" uses.

"F" The quality of these waters shall be maintained suitable for industrial water supply uses, other than food processing.

MONTANA WATER POLLUTION CONTROL COUNCIL - SURFACE WATER USE CLASSIFICATIONS OF MONTANA, OCT. 5, 1967.



WATER USE CLASSIFICATION

COLUMBIA BASIN

Clark Fork River Drainage

Clark Fork River:

Warm Springs Drainage to Myers Dam	A-Open-D_1
Remainder of Warm Springs Drainage	B-D_1
Silver Bow Creek (mainstem) from the confluence of Yankee Doodle and Blacktail Deer Creeks to Warm Springs Creek	For industrial waste use.
Yankee Doodle Creek Drainage to and including the Butte water supply reservoir	A-Closed
Remainder of Yankee Doodle Creek Drainage	B-D_1
Blacktail Deer Creek Drainage except portion of Basin Creek listed below:	B-D_1
Basin Creek Drainage to and including the Butte water supply reservoir	A-Closed
Remainder of Basin Creek Drainage	B-D_1
All other tributaries to Silver Bow Creek from the confluence of Yankee Doodle and Blacktail Deer Creeks to Warm Springs Creek	B-D_1
Clark Fork River (mainstem) from Warm Springs Creek to the Little Blackfoot River	C-D_2
Tin Cup Joe Creek Drainage to the Deer Lodge water supply intake	A-Closed
Remainder of Tin Cup Joe Drainage	B-D_1
Clark Fork River Drainage from the Little Blackfoot River to the Idaho line except those portions of tributaries listed below:	B-D_1
Georgetown Lake and tributaries above Georgetown Dam	A-Open-D_1
Flint Creek Drainage from Georgetown Dam to the Farm-to-Market Highway No. 348 bridge about one mile west of Philipsburg except those portions of tributaries listed below:	B-D_1
Fred Burr Lake and headwaters from source to the outlet of the lake	A-Closed

Flint Creek (mainstem) from Farm-to-Market Highway No. 348 bridge about one mile west of Philipsburg to the Clark Fork River	B-D_2
South Boulder Creek Drainage to the Philipsburg water supply intake	A-Open-D_1
Remainder of South Boulder Drainage	B-D_1
All other tributaries to Flint Creek from F-to-M Highway 348 bridge to the Clark Fork River	B-D_1
Rattlesnake Drainage to the Missoula water supply intake	A-Closed
Remainder of Rattlesnake Drainage	B-D_1
Packer and Silver Creek Drainage (tributaries to the St. Regis River) to the Saltese water supply intakes	A-Open-D_1
Remainder of Packer and Silver Creek drainages	B-D_1
Ashley Creek Drainage to the Thompson Falls water supply intake	A-Closed
Remainder of Ashley Creek Drainage	B-D_1
Pilgrim Creek Drainage to the Noxon water supply intake	A-Open-D_1
Remainder of Pilgrim Creek Drainage	B-D_1
All tributaries of Clark Fork River not otherwise mentioned	B-D_1

<u>Flathead River</u>

Flathead River Drainage (except tributaries in Glacier National Park or in nationally designated Wild, Wilderness, or Primitive areas) except tributaries and lakes or reservoirs listed below:	B-D_1
Essex Creek Drainage to the Essex water supply intake	A-Closed
Remainder of Essex Creek Drainage	B-D_1
Snyder Creek (mainstem) through the community of Lake McDonald in Glacier National Park to Lake McDonald	B-D_1
Stillwater River (mainstem) from (but excluding) Logan Creek to the Flathead River	B-D_2

Whitefish Lake and its tributaries	A-Open-D_1
Whitefish River (mainstem) from the outlet of Whitefish Lake to the Stillwater River	B-D_2
Haskill Creek Drainage to the Whitefish water supply intake	A-Open-D_1
Remainder of Haskill Creek Drainage	B-D_1
Remainder of Whitefish River Drainage	B-D_1
Remainder of Stillwater River Drainage	B-D_1
Ashley Creek Drainage to and including Smith (Kila) Lake	B-D_1
Ashley Creek (mainstem) from Smith Lake to bridge crossing on the airport road about one mile south of Kalispell	B-D_2
Ashley Creek (mainstem) from bridge crossing on the airport road to the Flathead River	E
All tributaries to Ashley Creek from Smith Lake to the Flathead River	B-D_1
Flathead Lake and its tributaries except Flathead River above the Lake (as listed above) Swan River and a portion of Hellroaring Creek as listed below, but including Swan Lake proper and Lake Mary Ronan	A-Open-D_1
Swan River Drainage (except Swan Lake proper)	B-D_1
Hellroaring Creek Drainage to the Polson water supply intake	A-Closed
Remainder of Hellroaring Creek Drainage	B-D_1
(Simply as a note for clarification, the Flathead River below the highway bridge at Polson to Paradise is included in the "B-D_1" classification of the Flathead River Drainage listed above.)	
Crow Creek Drainage to road crossing at Section 16, T20N, R20W about two and a half miles southwest of Ronan, except the portion of Second Creek listed below:	B-D_1
Second Creek Drainage to the Ronan water supply intake	A-Closed
Remainder of Second Creek Drainage	B-D_1
Crow Creek (mainstem) from road crossing in S16, T20N, R20W to the Flathead River	B-D_2

Tributaries to Crow Creek from road crossing in S 16 to the Flathead River	B-D_1
Little Bitterroot River Drainage to Hubbart Reservoir	B-D_1
Little Bitterroot River (mainstem) from Hubbart Reservoir Dam to the Flathead River	B-D_2
Tributaries to the Little Bitterroot River from Hubbart Reservoir Dam to the Flathead River except Hot Springs Creek listed below:	B-D_1
Hot Springs Creek Drainage to the Hot Springs water supply intake	A-Closed
Hot Springs Creek (mainstem) from the Hot Springs water supply intake to the Little Bitterroot River	E
Tributaries to Hot Springs Creek (if any) from the Hot Springs water supply intake to the Little Bitterroot River	B-D_1
Mission Creek Drainage to the St. Ignatius water supply intake	A-Open-D_1
Mission Creek Drainage from the St. Ignatius water supply intake to U.S. Highway No. 93 crossing about one mile west of St. Ignatius	B-D_1
Mission Creek (mainstem) from U.S. Highway No. 93 crossing to the Flathead River	B-D_2
Tributaries to Mission Creek from the U.S. Highway No. 93 crossing to the Flathead R.	B-D_1

<u>Kootenai River Drainage</u>

Kootenai River Drainage from the border of Canada to the Idaho border (including the Yaak River), except the tributaries listed below:	B-D_1
Deep Creek Drainage (tributary to the Tobacco River) to the Fortine water supply intake	A-Open-D_1
Sullivan Creek Drainage to the Rexford water supply intake	A-Closed
Rainy Creek Drainage to the Zonolite Company water supply intake	A-Open-D_1

Rainy Creek (mainstem) from the Zonolite Company water supply intake to the Kootenai River	D_2
Flower Creek Drainage to the Libby water supply intake	A-Open-D_1

MISSOURI BASIN

Missouri River Drainage

Missouri River:

Missouri River Drainage to the Sun River in Great Falls except tributaries listed below:	B-D_1
East Gallatin River (mainstem) (tributary to the Gallatin River, tributary to the Missouri River) from Montana Highway No. 293 crossing about one-half mile north of Bozeman to, but excluding, Dry Creek about five miles east of Manhattan	B-D_2
Remainder of the East Gallatin River Drainage except the tributaries listed below:	B-D_1
Lyman and Sourdough (Bozeman) Creek Drainages to the Bozeman water supply intakes	A-Closed
Remainder of the Lyman and Sourdough Creek Drainages	B-D_1
Hyalite Creek Drainage to the Bozeman water supply intake	A-Open-D_1
Remainder of the Hyalite Creek Drainage	B-D_1
Big Hole River Drainage (tributary to the Jefferson, tributary to the Missouri River) above Divide	A-Open-D_1
Remainder of the Big Hole Drainage	B-D_1
Rattlesnake Creek Drainage (tributary to the Beaverhead River, tributary to the Jefferson River) to the Dillon water supply intake	A-Open-D_1
Remainder of the Rattlesnake Creek Drainage	B-D_1
Indian Creek Drainage (tributary to the Ruby River, tributary to the Beaverhead River) to the Sheridan water supply intake	A-Open-D_1
Remainder of the Indian Creek Drainage	B-D_1
Basin Creek Drainage (tributary to the Boulder River, tributary to the Jefferson River) to the Basin water supply intake	A-Open-D_1
Remainder of the Basin Creek Drainage	B-D_1
Prickley Pear Creek Drainage to the Montana Highway No. 433 crossing about one mile northwest of East Helena, except the tributaries listed below:	B-D_1

McClellan Creek Drainage to the East Helena water supply intake	A-Open-D_1
Remainder of the McClellan Creek Drainage	B-D_1
Prickley Pear Creek (mainstem) from the Montana Highway No. 433 crossing about one mile northwest of East Helena to its mouth	E
Tributaries of Prickley Pear Creek from the Montana Highway No. 433 crossing to its mouth except those listed below:	B-D_1
Ten Mile Creek Drainage to the Helena water supply intake	A-Open-D_1
Remainder of Ten Mile Creek Drainage	B-D_1
Willow Creek Drainage (tributary of the Smith River, tributary to the Missouri River) to the White Sulphur Springs water supply intake	A-Closed
Remainder of the Willow Creek Drainage	B-D_1
Missouri River (mainstem) from Sun River to Rainbow Dam	B-D_2
Missouri River Drainage from Rainbow Dam in Great Falls to the North Dakota line except the portion of the mainstem and the tributaries listed below:	B-D_3
Sun River Drainage to, but excluding, Muddy Creek near Vaughn	B-D_1
Muddy Creek Drainage	E
Sun River (mainstem) from Muddy Creek to the Missouri River	B-D_3
Tributaries (if any) to the Sun River from Muddy Creek to the Missouri River	B-D_1
Belt Creek Drainage to and including Otter Creek except portion of O'Brien Creek listed below:	B-D_1
O'Brien Creek Drainage to the Neihart water supply intake	A-Open-D_1
Remainder of the O'Brien Creek Drainage	B-D_1
Belt Creek (mainstem) from Otter Creek to the Missouri River	B-D_2
Tributaries to Belt Creek from Otter Creek to the Missouri River	B-D_1
Highwood and Shonkin Creek Drainages	B-D_1

Marias River Drainage except tributaries listed below:	B-D_2
Cutbank Creek Drainage to, but excluding, Old Maid Miller Coulee in Cutbank except the portion of Willow Creek listed below:	B-D_1
Willow Creek Drainage to the Montana Highway 464 crossing about one-half mile north of Browning	B-D_1
Willow Creek (mainstem) from the Montana Highway No. 464 crossing to Cutbank Creek (also included in the Marias River Drainage classification above)	B-D_2
Tributaries (if any) to Willow Creek from the Montana 464 crossing to Cutbank Creek	B-D_1
Cutbank Creek (mainstem) from Old Maid Miller Coulee to Birch Creek (also listed under Marias above)	B-D_2
Tributaries to Cutbank Creek from, but excluding Old Maid Miller Coulee (which is "B-D_2") to Birch Creek	B-D_1
Birch Creek Drainage except tributaries listed below:	B-D_2
Two Medicine Creek Drainage to and including the Badger Creek Drainage	B-D_1
Midvale Creek Drainage to the East Glacier water supply intake	A-Closed
Remainder of Midvale Creek Drainage	B-D_1
Summit Creek Drainage to the Summit water supply intake	A-Closed
Remainder of Summit Creek Drainage	B-D_1
Two Medicine Creek (mainstem) from Badger Creek to Birch Creek	B-D_2
Tributaries to Two Medicine Creek from Badger Creek to Cutbank Creek	B-D_1
Teton River Drainage to and including Deep Creek near Choteau	B-D_1
Remainder of Teton River Drainage	B-D_2
Eagle Creek Drainage to but excluding Dog Creek	B-D_1

Remainder of Eagle Creek Drainage	B-D_3
Judith River Drainage to Big Spring Creek	B-D_1
Big Spring Creek Drainage to the Mill Ditch Headgate near the southern city limits of Lewistown	B-D_1
Big Spring Creek (mainstem) from the Mill Ditch Headgate to the Judith River	B-D_2
Tributaries to Big Spring Creek from the Mill Ditch Headgate to the Judith River	B-D_1
Judith River (mainstem) from Big Spring Creek to the Missouri River	B-D_2
Tributaries to the Judith River from Big Spring Creek to the Missouri River	B-D_1
Cow Creek Drainage to but excluding Al's Creek	B-D_1
Remainder of Cow Creek Drainage	B-D_3
Musselshell River Drainage to and including Hopley Creek near Harlowton	B-D_1
Musselshell River Drainage from Hopley Creek to but excluding Half Breed Creek near Roundup except American Fork listed below:	B-D_2
American Fork Drainage	B-D_1
Musselshell River Drainage from and including Half Breed Creek to Fort Peck Reservoir except Flatwillow Creek Drainage listed below:	B-D_3
Flatwillow Creek Drainage (may be the Box Elder Creek Drainage) near Mosby	B-D_2
Missouri River (mainstem) from Fort Peck Dam to the Milk River	B-D_2
Milk River Drainage from source (or from the Glacier National Park Boundary) to the International Boundary	B-D_1
Milk River Drainage from the International Boundary to the Missouri River except the tributaries listed below:	B-D_3
Big Sandy Creek Drainage above Big Sandy	B-D_1
Remainder of Big Sandy Creek Drainage	B-D_3
Beaver, Box Elder, and Clear Creek Drainages (all near Havre)	B-D_1

People's Creek Drainage to and including the South Fork of People's Creek	B-D_1
Remainder of People's Creek Drainage	B-D_3
Wolf Creek Drainage near Wolf Point	B-D_2
Poplar River Drainage	B-D_2

<u>Yellowstone River Drainage</u>

Yellowstone River Drainage from the Yellowstone Park Boundary to the Laurel water supply intake	B-D_1
Yellowstone River Drainage from the Laurel water supply intake to the Billings water supply intake, except the tributaries listed below:	B-D_2
Clark's Fork River Drainage from source to the Wyoming line and from the Wyoming line to and including Jack Creek near Bridger	B-D_1
Clark's Fork River (mainstem) from Jack Creek to the Yellowstone River	B-D_2
Tributaries to the Clark's Fork River from Jack Creek to the Yellowstone River except the West Fork of Rock Creek listed below:	B-D_1
West Fork of Rock Creek Drainage to the Red Lodge water supply intake	A-Open-D_1
Remainder of West Fork of Rock Creek Drainage	B-D_1
Yellowstone River Drainage from the Billings water supply intake to the North Dakota line except the tributaries listed below:	B-D_3
Pryor Creek Drainage	B-D_1
Big Horn Drainage above but excluding William's Coulee near Hardin	B-D_1
Big Horn Drainage from and including William's Coulee to the Yellowstone River except the Little Big Horn listed below:	B-D_2
Little Big Horn Drainage above and including Lodgegrass Creek near Lodgegrass	B-D_1
Remainder of the Little Big Horn Drainage	B-D_2

Tongue River (mainstem) from Tongue River Reservoir to but excluding Prairie Dog Coulee	B-D_2
Remainder of the Tongue River Drainage	B-D_3
Fox Creek Drainage near Sidney	B-D_2

Little Missouri and Belle Fourche Drainages:

All waters	B-D_3

HUDSON BAY DRAINAGE

All waters within Glacier National Park except the portion of Swiftcurrent Creek listed below:	A-Open-D_1
Swiftcurrent Creek (mainstem) from the Many Glacier Chalet to Lake Sherbourne	B-D_1
All waters outside Park from Park Boundary to the International Boundary	B-D_1

APPENDIX H

LIST OF EXISTING STORAGE PROJECTS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU.YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
FOUR HORNS	G1	004	BADGER CR.	VALIER		30N	8W	E	53.0	1,150	32,000				20,000	I
TWO MEDICINE	G2			BROWNING		31N	14W	E							14,000	I
LOW. TWO MEDICINE	G5			BROWNING		32N	13W	E	58.0	1,100		C	185	21,000	13,500	I
G2 & G5		003													27,500	
	G3	005	COULEE	CUT BANK	28	32N	7W	E	13.7	296	2,900	E	100	390	564	S
KIPF LAKE	G4	001	COULEE	BROWNING	1	32N	10W	E	16.0	1,422	12,300	C	800	3,422	5,009	S, I
SHERBOURNE LAKE	G6	101	SWIFT CURRENT CR.	BABB		36N	15W	E	96.0	1,086	228,000	C			66,100	FWI
	G7	002	COULEE	CUT BANK	22	37N	6W	E	18.0	465	9,020	E	150	500	1,466	FWS
	PD 1	018	RUNOFF	BRADY	36	27N	2E	E	24.0	372	14,548	E	30	244	120	FWS
DABNEY	PD 2	016	MARIAS TRIB.	DUPUYER	31	28N	7W	E	18.0	725	15,336	E/P	58/	570/42	80	I
TWIN & FISH LAKE	PD 3	006	MARIAS TRIB.	DUPUYER	30	28N	9W	E	19.0	670	13,926	E/P	30/	250/17	250	I
SWIFT DAM	PD 4	027	BIRCH CR.	DUPUYER	23	28N	10W	CA	205.0	573	54,000	C	326	34,000	31,000	I
LAKE FRANCIS	PD 5	015	RUNOFF	VALIER		29N	5W	E	40.0	600					112,000	I
BRAMLETTE	C1		RUNOFF	FT. BENTON	NWNE3	22N	8E	E	22.0	349	5,565	E/P	110/	700/100	54	FW
BOOTH DAM	C2		RUNOFF	FT. BENTON	SWSE11	22N	8E	E	38.0	591	57,082	E	50	660	700	FWI
HANDFORM DAM	C6		RUNOFF	FT. BENTON	NWSW22	23N	8E	E	24	186	6,346	E	10	38	56	FW

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU.YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
C1, C2, C6		402													810	
JERGENS DAM	C-3		RUNOFF	FT. BENTON	SENE27	22N	10E	E	16.0	647	8,035	E	10	54	136	S
THURSTON RES.	C-4		MUD SPRING COULEE	GERALDINE	13	22N	11E	E	14.0	300	4,320	E	75	450	58	S
C-3, C-4		406													194	
ROBERTSON DAM	C-5	401	RUNOFF	CARTER	SESE16	23N	5E	E	16.0	395	3,025	E	35	300	96	S
MOES DAM	C-7		RUNOFF	BIG SANDY	25	23N	15E	E	30.0	272	8,228	E	34	136	53	S
JAPPE DAM	C-8		RUNOFF	BIG SANDY	10	23N	15E	E	32.0	600	24,316	E	100	1,050	445	I
C-7, C-8		407													498	
ONSTAD DAM	C 9	026	RUNOFF	FT. BENTON	SWNW17	25N	5E	E	20.0	500	9,666	E	100	500	98	S
VIELLEUX, JOE	C10		RUNOFF	FT. BENTON	NENE 3	25N	7E	E	17	567	7,363	E	NAT. SOD	305	62	FWS
MILLER DAM	C14		RUNOFF	FT. BENTON	SENE33	26N	8E	E	21.0	414	8,020	E	30	234	94	S
C10, C14		025													156	
SILVAN	C11		RUNOFF	BIG SANDY	12	25N	13E	E	29.0	377	17,170	E/P	50	285	65	I
CHRISTOFFERSON	C12		12-MILE COULEE	BIG SANDY	25	25N	14E	E	17.0	215	890	E	100	660	260	S
WILLIAMS DAM	C16		DIV. FROM DOG CREEK	BIG SANDY	15	26N	15E	E	5.0	770		E	100	400	60	I
SEIFERT	C17		DIV. FROM DOG CREEK	BIG SANDY	28	26N	15E	E	20.0	2,589	22,703	E	300	2,000	1,005	I

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU. YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
C11, C12, C16, C17		405													1390	
KANE DAM	B1		SAND CR.	BIG SANDY	10	26N	17E	E	38.0	746	8,876	E/P	100	660	300	I
OLSON	C13		WORDEN CR.	BIG SANDY	5	25N	17E	E	27.0	530	34,000	E/P	60	372	70	I
MC LEISH	C18		LITTLE BIRCH	BIG SANDY	11	26N	16E	E	42.0	510	40,000	E/P	150	2,250	328	I
B1, C13, C18		408													698	
PEGAR FISH	C15		RUNOFF	BIG SANDY	28	26N	13E	E	24	309	12,174	E/P	40	238	65	FW
MAXWELL	C26		FORK OF ALKALI COULEE	BIG SANDY	36	27N	13E	E	17.0	502	2,758	E	40	128	56	S
SIBRA DAM	C25		DIV. FROM BIG DANDY	BIG SANDY	6/7	27N	13E	E	13.0	2,570	14,300	E/P			220	I
TURK DAM	C23		RUNOFF	BIG SANDY	14	27N	12E	E	20.0	225		E/P			120	S
KNATTNERUS DAM	C24			BIG SANDY	23	27N	12E	E	18.0	395	4,787	E	66	337	85	S
C15, C26, C25, C23, C24		404													546	
RAY DAM	C19		RUNOFF	FT. BENTON	NENE8	27N	5E	E	18.0	340	6,958	E	2 SPILLS		58	FWS
STEWART DAM	C20		RUNOFF	FT. BENTON	NWSE7	27N	6E	E	34.0	289	12,045	E	20	400	87	
C19, C20		020													145	
ROMAIN F POND	C27	022	RUNOFF	FT. BENTON	SESE6	28N	8E	E	24.0	796	15,117	E			64	FW
CORNETT FISH	C28	120	RUNOFF	BIG SANDY	4	28N	12E	E	21.0	582	9,888	E	100	410	68	FW

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU. YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
	C21			BIG SANDY	12	27N	10E	E	8.0	675	4,860	C	20	340	65	FW
	C22		SPRING COULEE	BIG SANDY	25	27N	10E	E	25.0	368	10,863	E	90	792	72	S
C21, C22		403														
															137	
MC CRACKEN	T1	019	RUNOFF	SHELBY	28	29N	3E	E	20.0	448	22,430	E	90	740	275	S
WESTERMARK DAM	T2	009	RUNOFF	DEVON	33	31N	1E	E	39	280	34,330	E	40	240	85	FW
WHITE DAM	T3	011	RUNOFF	DEVON	17	31N	2E	E	24.0	616	21,496	E	50	300	64	I
JOHNSON DAM	T4	008	RUNOFF	DUNKIRK	34	32N	1E	E	18.0	830	9,544	E	100	600	51	I
HE BENJAMIN JR.	T5		RUNOFF	SHELBY	17	33N	1W	E	25.0						EST. 200	I
LESTER FLESH	T7		RUNOFF	SHELBY	1	33N	2W	E	20.0	700	11,297	E	100	300	126	S
T5, T7		007														
															326	
CHILDER'S DAM	T6	010	RUNOFF	CALATA	33	33N	3E	E	11.0	1,844	22,740	E/P	60/30	360/100	840	I
POTTER DAM(ENL)	T8		RUNOFF	SHELBY	3	33N	3W	E	20.0	700	11,297	E	100	300	126	S
KOLSTAD DAM	T9		RUNOFF	CALATA	13	34N	2E	E	17.0	810	18,217	E	20	20	67	I
HENERY DAM	T10		DIV. FROM STRAWBERRY	CALATA	15	35N	3E	E	24.0	493	19,840	E	10	20	61	I
T9, T10		013														
															128	

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA – DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU.YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
BERTHELATE	T11		RUNOFF	SUNBURST	12	36N	1E	E	45.0	303	31,998	E/P	50/	300/30	200	I
TOMSHECK	T12		RUNOFF	SUNBURST	31	36N	1E								EST. 200	
T11, T12		012													400	
J. WALANSKI	T13		RUNOFF	SWEETGRASS	15	37N	1W	E	25.0	363	10,378	E	50	176	65	I
O'HAIRE DAM	T14		RUNOFF	SUNBURST	32	37N	1W	E							300	I
VAUGHN HOLLAND	T15		RUNOFF	SUNBURST	35	37N	1W	E							EST. 250	SW
T13, T14, T15		103													615	
A & A FEY	T16		RUNOFF	WHITLASH	12	37N	3E	E	24	355	18,233	E/P	40/30	240/100	145	I
W PARSELL	L5		RUNOFF	WHITLASH	26	37N	4E	E	26	670	19,260	E	90	54	54	I
T16, L5		104													199	
HILLSIDE COLONY DAM	T17	102	RUNOFF	SWEETGRASS	3	37N	4W	E	18	460	6,325	E/P	100/30	324	58	I
TIBER DAM	L1	017	MARIAS	SHELBY		30N	5E	E	205.0	4,300	9,290,000	C	96	54,250	11,386,000	FWT FCM
KAMERZELL DAM	L2	021	RUNOFF	CHESTER	13	31N	5E	E	16.0	1,700	20,700	E	200	1,400	90	S
LAAS DAM	L3	014	RUNOFF	CHESTER	15	33N	4E	E	10.0	1,006	9,900	E	615	4,305	132	SI

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU.YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
E.PARK RES.	H1		BEAVER CR.	BOX ELDER	23	28N	16E	E	48.0	229	20,000	E	20	500	75	M
	H8		BEAR PAW LAKE	HAVRE	28/33	30N	16E	E	57.0	382						
H1, H8		127													75	
	H2		BOX ELDER CR.	ROCKY BOY	1	29N	15E	E	60.0	425	100,000	R	80	4,100	1,400	I/S
	H3		BOX ELDER CR.	BOX ELDER	21	29N	15E	EC	40.0						60	I
H2, H3		122													1,460	
M. HAAS	H4	119	BIG SANDY TRIB	BOX ELDER	30	30N	11E	E	10.0	630	6,639	E			53	S
	H5	124	BOX ELDER CR.	BOX ELDER	27/28	30N	13E	E	10.0	2,640	30,000				1,200	S
SCHMIDTH RES.	H6	121	BARNEYS COULEE	BOX ELDER	29/30	30N	13E	E	11.0	200					52.8	S
BROWN RES.	H7	123	COULEE	ROCKY BOY	31	30N	14E	E	25.0	688	26,680	E	100	800	88	I/S
	H9		TRIB TO BLACK COULEE	INVERNESS	18	31N	8E	E	27.0	684		E	40			S
	H12		ROCK COULEE	INVERNESS	26	31N	8E	E	15.0	291		E	12			S
	H13		ROCK COULEE	INVERNESS	35	31N	8E	E	27.0	315		E	40			S
H9, H12, H13		024													750	
HOWARD GOODIAN	H10	117	SAGE CR.	BOX ELDER	28	31N	13E	E	23.0	340	9,532	E	100	280	202	I
BOYER RES.	H17		SPRING COULEE	LAREDO	15	31N	14E	E	20,0	200					90	I
	H11		GRAVELLY COULEE	LAREDO	22	31N	14E	E	20.0	1,300	17,689	E	700	1,810	240	I
H17, H11		125													330	

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU.YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
HILLDALE COLONY	H14		TRIB. TO RED ROCK	HAVRE	5	31N	13E	E	EST. 20.0	EST. 500	EST. 11,000	E	EST. 40	300	EST. 175	I/S
DEES BROS.	H15		TRIB. SAGE CR.	KREMLIN	5	31N	13E	E	20.0	400	9,000	E	50	150	60	W/L
H14, H15		116													235	
KIEMIE RES.	H16	118	OBRIAN COULEE	BOX ELDER	26	31N	13E	E	25.0	200					100	S/I
J.PASMA	H18	126	BIG SANDY TRIB.	HAVRE	22	32N	14E	E	19.0	600	6,000	E			83	S
H26, H27, H28,																
H29, H19, H21,																
H22, L4		115	INVERNESS					E							1,640	S
	H20	023	TRIB. TO BLACK COULEE	RUDYARD	27	31N	9E	E	15.0	252						S
JOHN MC SLAY	H23		MILK RIVER TRIB.	HAVRE	10	33N	14E	E	25.0	490	8,300	E			130	FW
D. MORSE	H35		MILK RIVER TRIB.	HAVRE	36	34N	14E	E	30.0	365	16,600	E	75	300	75	FW
H23, H35		108													205	
FRESNO	H24	107	MILK RIVER	HAVRE	32	33N	14E	E	111.0	2,070	2,105,000	C	210	51,000	129,000	FW/M I/FC
L. KROTT	H25	129	MILK R. TRIB.	HAVRE	23	33N	17E	E	22.0	300	9,086	E	75	98	80	FW
T. STEVENSON	H30		SAGE CR. TRIB.	GILDFORD	12	34N	10E	E	21.0	520	12,783	E	120	142	94	F/W
O'BRIAN 345-COULEE DAM	H31		MILK R. TRIB.	GILDFORD	21	34N	10E	E	20.0	677	30,000	E	150		350	I/S
H30, H31		113													444	

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU.YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
	H32		SAGE CR.	HINGHAM	21	34N	10E	E	13.0	1,326						I
	H33		SAGE CR.	HINGHAM	23	34N	10E	E	17.0	596						S/I
	H34		SAGE CR.	HINGHAM	24	34N	10E	E	10.0	540						S/I
H32, H33, H34		114														
LOHMAN RES.	H36	128	COAL COULEE	HAVRE	34	34N	15E	E	15.0	200					180	S
	H53		MARIETTA COULEE	HAVRE	8	36N	14E	E		1,100					200	S
MC LEAN RES.	H54		BLACK COULEE	HAVRE	21	36N	15E	E	10.0	520					800+	I
H53, H54		132													1,000	
KNUTSEN NO. 1	H37	135	TRIB. RED ROCK	HAVRE	7	34N	16E	E	EST. 20.0	EST. 600	EST. 12,000	E	EST. 50	EST. 410	EST. 175	S/W I
KNUTSEN NO. 2	H38		TRIB. RED ROCK	HAVRE	9	34N	16E	E	EST. 22.0	EST. 500	EST. 13,000	E	EST. 100	EST. 500	EST. 175	S/W I
THIBODEAU LAKE	H47		DITCH FROM MUD LAKE	HAVRE	26	35N	16E	E	10.0	100		E			300	S
THIBODEAU FARM	H48		TRIB. RED ROCK	HAVRE	33	35N	16E	E	EST. 18.0	EST. 1,000	EST. 15,000	E	EST. 100	EST. 50	EST. 150	WI S
H38, H47, H48		[illegible]													625	
	H39	112	LITTLE SAGE CR.	INVERNESS	19	35N	8E	E	30.0	503		E	78			S
	H40	111	TRIB. TO SAGE CR.	RUDYARD	13	35N	9E	E	25.0	939		E	50			I
			COULEE	GILDFORD	1	35										
H41, H51, H52		105														S

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU. YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
	H42	106	COTTONWOOD COULEE	HAVRE	1	35N	13E	E	20.0	500					240	S
H43, H44, H46		134													720	S
	H45	133	RED ROCK COULEE	HAVRE	29	35N	14E	E	15.0	150					180	S
A.C. LANGEL	H49	110	SAGE CR. TRIB.	RUDYARD	22	36N	9E	E	10.0	1,500	16,883	E			78	I
	H50		SAGE CR. TRIB.	RUDYARD	29	36N	9E	E	15	990						S
	H57		TRIB. SAGE CR.	INVERNESS	33	37N	8E	E	20.0	360		E	60			I
	H58		TRIB. SAGE CR.	INVERNESS	33	37N	8E	E	18.0	375		E	90			I
H50, H57, H58		109													750	
R. LENHART #4	H55		TRIB. LODGE CR.	HAVRE	23	36N	16E	E	EST. 25.0	EST. 600	EST. 15,000	E	125	EST. 200	200	FW/S
R. LENHART #5	H56		TRIB. SAGE CR.	INVERNESS	33	37N	8E	E	20.0	360		E	60			I
H55, H56		139													200	
	H59		BOUNDRY LINE COULEE	HAVRE	11	37N	13E	E	15.0	300		E				
	H60		COULEE	HAVRE	29	37N	14E	E							50	
H59, H60															50	
CREEDMAN	H61		CREEDMAN COULEE	HAVRE	15	37N	15E	E								
	H62		UNNAMNED COULEE	HAVRE	18	37N	15E	E							50	S

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU. YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
H61, H62		138													50	
H63, H64															500	
IU RESERVOIR	B2	409	MILK RIVER	LLOYD	16	27N	19E	E	50.0	1,150		E			780	I
	B3	122	COULEE	HARLEM	1	27N	22E	E	12.5	340	2,600	E	130	500	92	S
	B5	169	COULEE	HARLEM	23	27N	22E	E	14.0	230	9,240	E	100	500	400	S
	B4		SUCTION CR.	HAYES	10	27N	22E	E	EST. 20.0						EST. 400	I/S
	B6		SUCTION CR.	HAYES	30	28N	22E	E	5.0	1,320 EST.					480	I/S
B4, B6															880	
	B7	165	COULEE	SAVOY	4	28N	24E	E	12.0	408	2,160	E	120	700	60	S
	B8		SNAKE CREEK	CHINOOK	5	29N	19E	E	18.0	800		E				I
	B20		SNAKE CREEK	CHINOOK	12	30N	19E	E	8.0	612		E				I
	B21		MILES CREEK	CHINOOK	14	30N	19E	E	3.0	519		E				I
	B28		BEAN CREEK	LLOYD	26	31N	19E	E	13.0	993						I
	B29		BEAN CREEK	LLOYD	26	31N	19E	E	13.0	993						I
	B30		GRASSHOPPER COULEE	LLOYD	29	31N	19E	E	28.0	468						I
B-8, B20, B21, B28, B29, B30																

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	NEAREST TOWN	SEC.	TWP.	RGE.	STRUCTURE DATA: DAM: TYPE	HEIGHT	LENGTH OF CREST	VOLUME CONTENT (CU.YARDS)	SPILLWAY: TYPE	WIDTH	CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
	B9		ROSS CREEK	CLEVELAND	6	29N	20E	E	23.0	495						S
NO. 6	B22		BOX ELDER	CHINOOK	9	30N	20E	E	32.0	1,035		E	12			I
	B23		TRIB. TO BOX ELDER	CLEVELAND	22	30N	20E	E	22.0	460		E	2 SPILLS 5' EACH			S
	B11		TRIB. TO BOX ELDER	CLEVELAND	33	29N	20E	E	30.0	728						S
B9, B22, B23, B11		157													1,000	
	B10	164	CLEVELAND CR. TRIB. PEOPLES	CLEVELAND	16/21	29N	20E	E	50.0	330		E	12			S
	B12	166	MAGGIES CR.	CLEVELAND	10	29N	21E	E	20.0 EST	200 EST.					320 EST.	S
B13, B14		167													360	S
	B15		COULEE	HARLEM	1	29N	22E	E	6.0	255	1,045	E	60	460	147	S
B16, B17																
B18, B19		170	COULEE	SAVOY				E				E			1,297	S
	B31	160	COULEE	HARLEM	9, 10 11, 14	31N	22E	E	10.9	1,135	15,075	E	150	900	720	S
	B24	159	COULEE	SAVOY	6	30N	24E	E	11.0	370	3,580	E	150	350	120	S
	B25	172	COULEE	SAVOY	35	30N	25E	E				E	70	300	75	S
	B26		CLEAR CREEK	CHINOOK	5	31N	18E	E							APP. 475	I
	B27		CLEAR CREEK	CHINOOK	5/8	31N	18E	E							APP. 350	I
B26, B27		130													825	

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION					STRUCTURE DATA								PURPOSE
								DAM				SPILLWAY				
			SOURCE OF WATER (STREAM OR TRIB.)	NEAREST TOWN	SEC.	TWP.	RGE.	TYPE	HEIGHT	LENGTH OF CREST	VOLUME CONTENT (CU. YARDS)	TYPE	WIDTH	CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	
PARADISE DIV.	B32	137	MILK RIVER	CHINOOK	6	32N	20E	C	9.0	190	13,000	OC		6,800	MINOR	I
B33, B34		152						E							171	S
BR-52	B35	155	WAYNE CREEK	HARLEM	15/16 2	32N	23E	E	18.8	408	7,398	E	210	484	71	S
BR-38	B36	163	DODSON CREEK	DODSON	12	32N	25E	E	20.0		5,167	E			55.3	S
	B37	149	CORRAL COULEE	CHINOOK	21	33N	20E	E	36.0	400	25,000				128	S
BR-43	B38		30 MILE	CHINOOK	24	33N	22E	E	26.0	370	11,430	E	40	983	101	S
	B46		W FORGEY CR.	HARLEM	33	34N	22E	E	20.0						EST. 120	
B38, B46		154													221	
	B39	151	COULEE	HARLEM	32	33N	22E	E	EST. 13.0						EST. 300	S/I
BR-8	B40	136	RED ROCK CR.	LOHMAN	19	34N	18E	E	12.0	417	3,673	E	40	594	86.6	S
B41, B42																
B43, B45		150		CHINOOK				E							191.4	S
B60, B44		141						E							12	S
B47, B48		156		CHINOOK				E				E			135.9	S
BR-40	B49	179	BLACK COULEE	DODSON	18	34N	25E	E	15.0		4,450	E			227.5	S
B50, B57		140	HAY COULEE	LOHMAN				E							500	S

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU.YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
NORTH CHINOOK	B51	146	OFFSTREAM	CHINOOK	24	35N	18E	E							7,000	I
BAIRD RES.	B53		W FORK 30 MILE	ZURICH	9	35N	21E	E							200	S/I
RICHMOND RES.	B54		COULEE	ZURICH	17	35N	21E	E	15.0						108	S
BAIRD RES.	B55		W FORK 30 MILE	ZURICH	19	35N	21E	E							300	S/I
BR-57	B56		30 MILE	CHINOOK	4	35N	22E	E	17.5		14,284	E			57.4	FW/S
B53, B54															665.4	
B55, B56		153														
STEPHENS	B58	142	BENNETT COOKE	CHINOOK	4	36N	20E	E	24.0	406	16.198	E	100	563	480	I
	B59	147	BRANCH HORSE CORRAL COULEE	CHINOOK	35	36N	20E	E	30.0	510	51,000	E	2 RDS			S
TRIB. FROM CANADA	B61	144	UNNAMNED COUL	CHINOOK	5	37N	18E	E	6.0	100		E			APP. 16	S
BR-22	B62		BATTLE CR.	CHINOOK	10	37N	18E	E	12.0		5,985				75.9	S
	B64		TRIB. TO E. FORK BATTLE CR	CHINOOK	3	37N	19E	E	12.0	306						I/S
B62, B64		144													75.9	
B63, B68		145													500	S
	B65		TRIB. TO E. FORK BATTLE CR.	CHINOOK	4	37N	19E	E	5.0	300						I/S
BR-55	B66		BATTLE CR.	CHINOOK	7	37N	19E	E	15.4	341	4,417	E	250	3,440	80	S
B65, B66		144													80	

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU.YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
BR-45	B67	140	BATTLE CR.	CHINOOK	29	37N	19E	E	18.0	8,400		E			85.5	S
	B69	143	BENNETT COULEE	CHINOOK	23	37N	20E	E	24.4	430 & 420 DIKE	11,100	E	240		65	I/FC
	B70	181	COULEE	HOGELAND	10	37N	23E	E	15.0	1,056		E	10		250	S
KANE DAM	B-1	408	SAND CR.	BIG SANDY	10	26N	17E	E	38.0	746	8,876	E/P	100	660	300	I
	P-1		N. FORK FOURCHETTE	MALTA	10	23N	29E	E	14.0	1,515	12,000	E	340	1,933	53	IS
PR-115	P-5		FOURCHETTE CR.	MALTA	35	24N	29E	E	20.0		14,284	E			57.4	FWS
PR-137	P-6		TELEGRAPH CR.	MALTA	15	24N	30E	E	28.7	585	16,576	E	200		51.7	S
	P-7			MALTA	20	24N	30E	E	10.0	1,294	14,766	E	78	500	56	I,S
HOLZHEY	P10		FIRST CREEK	MALTA	31	25N	31E	E	18.0	2,500	87,469	E	300	2,600	1,040	I,S
P-1, P-5, P-6																
P-7, P10		412													1,258.1	
PR-18	P-2		DRY FORK CR.	MALTA	8	24N	27E	E	24.0	435	15,952	E	165	1,376	64	FWS
PR-35	P-3		DRY FORK CR.	MALTA	8	24N	27E	E	24.0		12,543	E			56.7	FWS
PR-11	P-4		DRY FORK CR.	MALTA	13	24N	27E	E	16.0	262	4,923	E	133	2,780	401	S
P-2, P-3, P-4		411	DRY FORK CR.	MALTA				E				E			521.7	

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU.YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
PR-147	P-8	186	BEAVER CR.	MALTA	23	25N	28E	E	18.0	451	7,973	E	180	2,746	60.8	S
	P-9	187	COULEE	REGINA	5	25N	30E	E	29.0	338	15,952	E	46.6	1,344	64	S
P11, P12, P13		188	BEAVER CR.	MALTA				E				E			512.75	S
PR-16	P14		BEAVER CR.	MALTA	13	27N	26E	E	24.0	250	8,160	E	43	1,122	60.12	FWIS
P15, P19, P20		177		MALTA				E				E			641.74	S
PR-109A	P16	189	BEAVER CR.	MALTA	8	27N	33E	E	25.0	370	12,527	E	245	13,582	56.5	FWS
P17, P21, P22		177						E				E			488	S
	P18	184	COULEE	SAVOY	20	28N	26E	E	17.3	332	6,200	E	250	350	54	S
PR-77	P23	176	MILK RIVER	MALTA	22	29N	28E	E	15.0		5,183	E			130.25	S
DRABBELS	P24		UNNAMNED TRIB.	MALTA	1	29N	30E	E	29.0	383	19,759	E	105	612	125	FWS
PR-36	P25		MILK RIVER	MALTA	20	29N	30E	E	17.8	294	5,725	E	285	2,175	57.7	S
P24, P25		182													182.7	
DODSON DIVER.	P26	174	MILK RIVER	DODSON		30N	26E	C	26.0	8,154	87,400	OVERFLOW CREST		1,450		I
	P27	173	COULEE	DODSON	15	30N	26E	E	10.0	495	1,590	E	40	320	153	S
P28, P29, P30		178		DODSON				E				E			213.4	S

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU.YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
PR-40	P31	190	BEAVER CR.	MALTA	21	31N	33E	E	19.1		11,703	E			103.23	FWS
	P32		UPPER DODSON CR.	DODSON	2	32N	27E	E	10.0	1,785	17,302	E	100	575	456	FWS
PR-56	P34		ASSINABOINE RIVER	DODSON	24	33N	26E	E	19.0	440	8,574	E	155	2,072	912.1	S
PR-98	P35		ASSINABOINE RIVER	DODSON	33	33N	27E	E	11.5		5,491	E			196	S
P32, P34, P35		175													1,564.1	
PR-100	P36		COTTONWOOD	MALTA	2	34N	28E	E	17.4	245	6,654	E	320	1,441	100	FWS
PR-100	P37		COTTONWOOD	MALTA	15	34N	28E	E	20.5		15,632	E			73.6	S
P36, P37		180													173.6	
714-FRENCHMAN	P38	193	FRENCHMAN CR.	SACO		34N	34E	E	41.0	DIKE 2062 DAM 498	83,000	C	125	12,000	7.010	I
P39, P40		192						E				E			893.22	S
PR-86	P41		WHITEWATER	WHITEWATER	6	37N	31E	E	20.0		5,624	E			62	FWS
PR-156	P42		WHITEWATER	WHITEWATER	7	37N	32E	E	16.0		12,539	E			95.6	S
PR-88	P43		WHITEWATER	WHITEWATER	29	37N	32E	E	14.1		3,301	E			358.6	S
P41, P42, P43		191													516.2	
NELSON	P33		OFFSTREAM MILK RIVER	SACO		32N	32E	E	28.0	9,900	233,000				85,000	FWI

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU. YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
V1, V4, V19																
V20, V21, V22															1,043	FCS
V23		283		GLASGOW				E				E				
V2, V3, V5																
V16, V12, V9																
V10, V12, V13																
V14, V15, V18																
V27, V28, V25		209		GLASGOW				E				E			1,522.8	FCS
V6, V8, V35																
V36, V37, V38																
V39, V40, V11																
V41, V42, V43																
V44, V45, V57																
V59, V60, V61																
V68, V70, V7		208		GLASGOW				E				E			10,050.45	FCS
FORREST DET.	V26	211	WILLOW CR.	GLASGOW	27	25N	37E	E	28.0	2,974	102,694	P/E	54/	350/	25/954	FCS
GUTSHOT DET.	V51	212	LONETREE CR.	GLASGOW	34	26N	37E	E	43.5	1,999	154,185	P/E	48/100	350/960	660.7/ 3175.5	FC FWS

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION: SOURCE OF WATER (STREAM OR TRIB.)	LOCATION: NEAREST TOWN	LOCATION: SEC.	LOCATION: TWP.	LOCATION: RGE.	STRUCTURE DATA: DAM: TYPE	DAM: HEIGHT	DAM: LENGTH OF CREST	DAM: VOLUME CONTENT (CU.YARDS)	SPILLWAY: TYPE	SPILLWAY: WIDTH	SPILLWAY: CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
DROP COLLINS HEADCUT	V24	214	WILLOW CR.	GLASGOW	25	25N	37E	E	40	3,571	186,329	P/E	60/	434/	295/ 1,335	FCS
V29, V30																
V31, V32, V33																
V34, V52		215		GLASGOW				E				P/E			2,057	FCS
V46, V67, V49																
V50, V48, V62																
V63, V64, V65																
V66, V56, V58																
V71, V72, V47																
V79, V69		210	BEAVER CR.					E				P/E			8,102.69	FCS
V75, V76																
V53, V74, V54		217	SAGE HEN CR.	GLASGOW				E				P/E			2,226.6	FCS
FORT PECK	V55	413	MISSOURI	GLASGOW		26N	41E	E	250.5	21,026	125,628,000	C		820, 250,000	19,100,000	NFC PI
V73, V77		216		GLASGOW				E				P/E			687.4	FCS
VR-2	V78	204	BRAZIL CR.	GLASGOW	23	28N	36E	E	22.5	1,634	52,771	P/E			1330	FC FWS
	V80	207	COULEE	NASHUA	22	28N	42E	E	23.0	380	7,952	E	200	786	58.2	S
V81, V82		414	COULEE	NASHUA				E				E			189.4	S

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION					STRUCTURE DATA								
								DAM				SPILLWAY				
			SOURCE OF WATER (STREAM OR TRIB.)	NEAREST TOWN	SEC.	TWP.	RGE.	TYPE	HEIGHT	LENGTH OF CREST	VOLUME CONTENT (CU.YARDS)	TYPE	WIDTH	CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	PURPOSE
VR-14	V83	203	BRAZIL CR.	GLASGOW	30	29N	37E	E	12.5		5,556	E			135	FWS
HANSON DAM	V84	205	RUNOFF	GLASGOW	29	29N	40E	E	16.0	304	6,682	E	70		50	FWS
VANDALIA DIV.	V85	200	MILK RIVER	VANDALIA		30N	36E	C	32.0	2,350	15,200	OVERFLOW CREST				I
KIELMAN DAM	V86	201	RUNOFF	VANDALIA	19	31N	32E	E	20.0	560	16,396	E	75	EST. 250	74	I
ELKSWORTH DAM	V87		RUNOFF	HINSDALE	12	31N	37E	E	22.0	307	7,264	E	56	260	60	S
CORNWELL DAM	V88		RUNOFF	GLASGOW	12	31N	38E	E	26.0	400	12,000	E	100	EST. 600	250	I
WAGNER DAM	V89		RUNOFF	GLASGOW	32	31N	36E	E	8.0	889	5,116	E	NAT.	862	71	I
VR-80	V90		ROCK CREEK	GLASGOW	31	32N	37E	E	22.0		15,607	E			70	FCS
V87, V88																
V89, V90		202													451	
VR-64	V91	198	ROCK CREEK	GLASGOW	14	33N	37E	E	14.0		8,514	E			55.9	FWS
NEUFELD # 1	V92		RUNOFF	LARSON	20	34N	41E	E	25.0	975	18,300	E	200	1,250	100	FC
NEUFELD # 2	V93		RUNOFF	LARSON	20	34N	41E	E	20.0	671	17,500	E	100	710	85	FC
V92, V93		206													185	
VR-72	V94	197	ROCK CREEK	GLASGOW	33	35N	35E	E	14.0		6,733	E			979	FWS
DYNCAN DAM	V95		RUNOFF	THOENY	6	35N	36E	E	29.0	324	18,300	E	40	200	70	S
DYNCAN NO. 2	V98		RUNOFF	THOENY	25	36N	35E	E	19.0	600	16,460	E	184	640	200	I
V95, V98		196													270	

REFERENCE: MONTANA REGISTER OF DAMS

EXISTING DAMS 50 AC-FT & LARGER

NAME OF DAM	PROJECT NO.	MODEL NO.	LOCATION					STRUCTURE DATA								PURPOSE
								DAM				SPILLWAY				
			SOURCE OF WATER (STREAM OR TRIB.)	NEAREST TOWN	SEC.	TWP.	RGE.	TYPE	HEIGHT	LENGTH OF CREST	VOLUME CONTENT (CU.YARDS)	TYPE	WIDTH	CAPACITY CFS	CAPACITY OF RESERVOIR (AC. FT.)	
ETCHART DAM	V96	199	RUNOFF	HINSDALE	16	35N	38E	E	18.0	450	8,000	E	NAT.	400	100	S
TARUM DAM	V97	415	RUNOFF	RICHLAND	14	35N	43E	E	16.0	400	9,150	E	140		50	S
BEIL DAM	V99	19	RUNOFF	THOENY	4	36N	36E	E	15.0	384	7,433	E	41	205	60	S
HUNTER DAM	V100		RUNOFF	THOENY	10	37N	36E	E	24.0	500	13,000	E	NAT.	600	100	I
VR-77	V101		ROCK CREEK	GLASGOW	34	37N	38E	E	18.4		11,662	E			73.43	FCS
V100, V101		194													173.43	

REFERENCE: MONTANA REGISTER OF DAMS

APPENDIX I - OUTDOOR RECREATION INVENTORY & ESTIMATED DEMAND

TABLE II-1

* LOCAL INVENTORY OF OUTDOOR RECREATIONAL LAND AND FACILITIES IN STUDY AREA, IN ACRES, 1969

County	Distribution of Acreage			Bureau of Outdoor Recreation Class or Type of Site			
	Land	Water	Total	Class 1 High Density	Class 2 General Outdoor	Class 3 Natural Enviornment	Class 6 Historic & Cultural Sites
Valley	78		78	24	32	22	
Phillips	5		5	1	4		
Blaine	402		402		82	120	200
Hill	10,000		10,000		560	9,440	
Liberty	12		12	7	5		
Toole	239	3	242	12	17	213	
Chouteau	7		7	2	5		
Pondera	39		39	2	13	24	
Glacier	15		15		15		
Total Study Area	10,797	3	10,800	48	733	9,819	200

County	Type of Recreational Acreage							
	Playing Field (Acres)	Swimming Beach (Acres)	Swimming Pool (Acres)	Picnic Area (Acres)	Boat Access (Acres)	Tent Camping (Acres)	Trailer Camping (Acres)	Group Camping (Acres)
Valley	18		6,400	8		1	1	
Phillips	1			1		1		
Blaine	11			50		24	34	60
Hill	40	1	1,500	100		200	60	200
Liberty	2	1		2				
Toole	4	1		9		10	10	1
Chouteau	1		800	1		1	1	
Pondera	8		4,800	2		1		
Glacier				4			1	1
Total Study Area	85	3	13,500	177		238	107	262

*Includes only municipal and county facilities.

TABLE II-2

*LOCAL INVENTORY OF OUTDOOR RECREATIONAL LAND AND FACILITIES IN STUDY AREA, 1969

County	Type of Recreational Acreage							
	Ice Skating (Acres)	Ski Slope (Acres)	Vista Point (Acres)	Marina (Acres)	Golf Course (Acres)	Horse Trail (Acres)	Foot Trail (Acres)	Bicycle Path (Acres)
Valley								
Phillips								
Blaine							2	
Hill							4	
Liberty	1							
Toole	1							
Chouteau	1							
Pondera								
Glacier	1							
Total Study Area	4						6	

County	Type and Number of Units at Sites							
	Picnic Tables	Boat Access Parking Spaces	Tent Spaces	Trailer Spaces	Group Camping (No. of Persons)	Marina Slips and Moorings	Ski Lift (Capacity Per Hour)	Golf Holes
Valley	16		10		50			
Phillips	9	12	12					
Blaine	17		6	5	50			
Hill	261		100	85	425			
Liberty	3							
Toole	52		35	39				
Chouteau	24	1	6	4				
Pondera	10		10					
Glacier	10				20			
Total Study Area	402	13	179	133	545			

*Includes only municipal and county facilities.

TABLE II-3

1970 ESTIMATED DEMAND FOR OUTDOOR RECREATION IN MONTANA, IN ACTIVITY DAYS

	County	Swimming	Pleasure Driving	Walking	Playing Games	Sight-seeing	Picknicking	Fishing	Bicycling
Resident	Valley	105,502	130,633	95,994	81,730	71,316	143,990	190,176	41,205
	Phillips	26,124	32,347	23,769	20,238	17,659	35,654	47,090	10,203
	Blaine	36,134	44,741	32,877	27,992	24,425	49,315	65,134	14,112
	Hill	76,508	94,732	69,612	59,269	51,717	104,418	137,911	29,880
	Liberty	10,942	13,548	9,956	8,476	7,396	14,933	19,723	4,273
	Toole	32,331	40,032	29,417	25,046	21,855	44,126	58,279	12,627
	Chouteau	32,331	40,032	29,417	25,046	21,855	44,126	58,279	12,627
	Pondera	34,232	42,386	31,147	26,519	23,140	46,721	61,706	13,370
	Glacier	58,455	72,379	53,187	45,284	39,514	79,780	105,370	22,830
	Subtotal	412,559	510,830	375,376	319,600	278,877	563,063	743,668	161,127
Nonresident	Valley	42,203		75,363		294,218	30,145	99,178	
	Phillips	42,203		75,363		294,218	30,145	99,178	
	Blaine	41,648		74,372		290,346	29,749	97,873	
	Hill	40,908		73,049		285,185	29,220	96,133	
	Liberty	29,987		53,547		209,049	21,419	70,468	
	Toole	40,352		72,058		281,313	28,823	94,828	
	Chouteau	24,989		44,623		174,208	17,849	58,724	
	Pondera	33,318		59,497		232,277	23,799	78,298	
	Glacier	67,933		121,308		473,587	48,523	159,642	
	Subtotal	363,541		649,180		534,401	259,672	854,322	
	Total	776,100		1,024,556		813,278	822,735	1,597,990	

TABLE II-3 (cont.)

1970 ESTIMATED DEMAND FOR OUTDOOR RECREATION IN MONTANA, IN ACTIVITY DAYS

	County	Hunting	Sailing	Canoeing	Mountain Climbing	Snow Skiing	Golfing	Motor to-bogganing	Snow Playing	Ice Skating
Resident	Valley	42,563	1,811	1,585	1,132	27,847	16,527	9,056	37,809	35,318
	Phillips	10,539	448	392	280	6,895	4,092	2,242	9,362	8,745
	Blaine	14,578	620	543	388	9,537	5,660	3,102	12,949	12,096
	Hill	30,866	1,313	1,149	821	20,194	11,985	6,567	27,418	25,612
	Liberty	4,414	188	164	117	2,888	1,714	939	3,921	3,663
	Toole	13,043	555	486	347	8,534	5,065	2,775	11,586	10,823
	Chouteau	13,043	555	486	347	8,534	5,065	2,775	11,586	10,823
	Pondera	13,810	588	514	367	9,036	5,363	2,938	12,268	11,460
	Glacier	23,583	1,004	878	627	15,429	9,157	5,018	20,948	19,569
	Subtotal	166,439	7,082	6,197	4,426	108,894	64,628	35,412	147,847	138,109
Nonresident	Valley									
	Phillips									
	Blaine									
	Hill									
	Liberty									
	Toole									
	Chouteau									
	Pondera									
	Glacier									
	Subtotal									
	Total									

TABLE II-3 (cont.)

1970, ESTIMATED DEMAND FOR OUTDOOR RECREATION IN MONTANA, IN ACTIVITY DAYS

	County	Other Boating	Camping	Sports Events	Horse Riding	Nature Walks	Hiking	Water Skiing	Outdoor Concerts
Resident	Valley	89,428	99,616	24,904	52,072	17,433	14,263	39,394	5,886
	Phillips	22,144	24,666	6,167	12,894	4,317	3,532	9,754	1,458
	Blaine	30,628	34,118	8,529	17,834	5,971	4,885	13,492	2,016
	Hill	64,851	72,239	18,060	37,761	12,642	10,343	28,567	4,269
	Liberty	9,275	10,331	2,583	5,400	1,808	1,479	4,086	610
	Toole	27,405	30,527	7,632	15,957	5,342	4,371	12,072	1,804
	Chouteau	27,405	30,527	7,632	15,957	5,342	4,371	12,072	1,804
	Pondera	29,017	32,322	8,081	16,896	5,656	4,628	12,782	1,910
	Glacier	49,549	55,194	13,798	28,851	9,659	7,903	21,827	3,261
	Subtotal	349,702	389,540	97,386	203,622	68,170	55,775	154,046	23,018
Nonresident	Valley	9,044	88,928	24,116	28,337	165,799	75,363	3,015	
	Phillips	9,044	88,928	24,116	28,337	165,799	75,363	3,015	
	Blaine	8,925	87,758	23,799	27,964	163,617	74,372	2,975	
	Hill	8,766	86,198	23,376	27,467	160,709	73,049	2,922	
	Liberty	6,426	63,186	17,136	20,134	117,804	53,547	2,142	
	Toole	8,647	85,028	23,058	27,094	158,527	72,058	2,882	
	Chouteau	5,355	52,655	14,279	16,778	98,170	44,623	1,785	
	Pondera	7,140	70,207	19,039	22,371	130,894	59,497	2,380	
	Glacier	14,557	143,144	38,819	45,612	266,878	121,308	4,852	
	Subtotal	77,904	766,032	207,737	244,094	428,197	649,180	25,968	
	Total	427,606	1,155,572	305,123	447,716	496,367	704,955	180,014	

TABLE II-4

1985 ESTIMATED DEMAND FOR OUTDOOR RECREATION IN MONTANA, IN ACTIVITY DAYS

	County	Swimming	Pleasure Driving	Walking	Playing Games	Sight-seeing	Picnicking	Fishing	Bicycling
Resident	Valley	150,511	156,329	130,274	117,373	94,607	175,048	214,004	49,833
	Phillips	37,271	38,712	32,260	29,065	23,427	43,347	52,993	12,340
	Blaine	51,551	53,544	44,620	40,201	32,403	59,955	73,297	17,068
	Hill	109,147	113,366	94,472	85,116	68,607	126,940	155,190	36,138
	Liberty	15,613	16,216	13,514	12,175	9,814	18,158	22,199	5,169
	Toole	46,124	47,907	39,923	35,969	28,993	53,644	65,582	15,271
	Chouteau	46,124	47,907	39,923	35,969	28,993	53,644	65,582	15,271
	Pondera	48,838	50,725	42,271	38,085	30,698	56,799	69,440	16,170
	Glacier	83,395	86,619	72,182	65,034	52,420	96,991	118,575	27,612
	Subtotal	588,574	611,325	509,439	458,987	369,962	684,526	836,862	194,872
Nonresident	Valley	71,484		127,650		498,346	51,060	167,988	
	Phillips	71,484		127,650		498,346	51,060	167,988	
	Blaine	70,544		125,971		491,789	50,388	165,777	
	Hill	69,289		123,731		483,046	49,492	162,830	
	Liberty	50,791		90,699		354,088	36,279	119,360	
	Toole	68,349		122,051		476,489	48,821	160,620	
	Chouteau	42,326		75,582		295,073	30,233	99,466	
	Pondera	56,435		100,776		393,431	40,311	132,622	
	Glacier	115,064		205,472		802,162	82,189	270,401	
	Subtotal	615,766		1,099,582		4,292,770	439,833	1,447,052	
	Total	1,204,340		1,609,021		4,662,732	1,124,359	2,283,914	

TABLE II-4 (cont.)

1985 ESTIMATED DEMAND FOR OUTDOOR RECREATION IN MONTANA, IN ACTIVITY DAYS

	County	Hunting	Sailing	Canoeing	Mountain Climbing	Snow Skiing	Golfing	Motor To-bogganing	Snow Playing	Ice Skating
Resident	Valley	45,280	2,024	1,771	1,265	31,114	18,466	10,118	42,244	39,462
	Phillips	11,213	501	438	313	7,704	4,573	2,506	10,461	9,772
	Blaine	15,509	693	607	433	10,657	6,325	3,466	14,469	13,516
	Hill	32,836	1,468	1,284	917	22,563	13,391	7,338	30,634	28,617
	Liberty	4,697	210	184	131	3,226	1,916	1,050	4,382	4,093
	Toole	13,876	620	543	388	9,535	5,659	3,101	12,946	12,093
	Chouteau	13,876	620	543	388	9,535	5,659	3,101	12,946	12,093
	Pondera	14,692	657	575	410	10,096	5,992	3,283	13,707	12,805
	Glacier	25,089	1,121	981	701	17,240	10,232	5,606	23,407	21,865
	Subtotal	177,068	7,914	6,926	4,946	121,670	72,213	39,569	165,196	154,316
Nonresident	Valley									
	Phillips									
	Blaine									
	Hill									
	Liberty									
	Toole									
	Chouteau									
	Pondera									
	Glacier									
	Subtotal									
	Total									

TABLE II-4 (cont.)

1985, ESTIMATED DEMAND FOR OUTDOOR RECREATION IN MONTANA, IN ACTIVITY DAYS

	County	Other Boating	Camping	Sports Events	Horse Riding	Nature Walks	Hiking	Water Skiing	Outdoor Concerts
Resident	Valley	128,251	153,800	31,367	66,023	20,996	20,490	70,070	8,348
	Phillips	31,758	38,085	7,767	16,349	5,199	5,074	17,351	2,067
	Blaine	43,927	52,677	10,743	22,613	7,191	7,018	23,999	2,859
	Hill	93,004	111,532	22,747	47,878	15,266	14,859	50,813	6,054
	Liberty	13,304	15,954	3,254	6,849	2,178	2,125	7,269	866
	Toole	39,303	47,132	9,613	20,233	6,434	6,279	21,473	2,558
	Chouteau	39,303	47,132	9,613	20,233	6,434	6,279	21,473	2,558
	Pondera	41,615	49,905	10,178	21,423	6,813	6,649	22,736	2,709
	Glacier	71,061	85,217	17,380	36,582	11,633	11,353	38,824	4,625
	Subtotal	501,526	601,434	122,662	258,183	82,104	80,126	274,008	32,644
Nonresident	Valley	15,318	150,627	40,848	47,996	280,830	127,650	5,106	
	Phillips	15,318	150,627	40,848	47,996	280,830	127,650	5,106	
	Blaine	15,116	148,645	40,311	47,365	277,135	125,971	5,039	
	Hill	14,848	146,003	39,594	46,523	272,208	123,731	4,949	
	Liberty	10,884	107,025	29,024	34,103	199,537	90,699	3,628	
	Toole	14,646	144,021	39,056	45,891	268,513	122,051	4,882	
	Chouteau	9,070	89,187	24,186	28,419	166,218	75,582	3,023	
	Pondera	12,093	118,916	32,248	37,892	221,708	100,776	4,031	
	Glacier	24,657	242,457	65,751	77,257	452,038	205,472	8,219	
	Subtotal	131,950	297,508	351,866	413,442	1,419,017	1,099,582	43,983	
	Total	633,475	898,942	474,528	671,625	1,501,121	1,179,708	317,991	